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HELIOTROPIC ANIMALS AS PHOTOMETERS ON THE BASIS OF THE VALIDITY OF THE BUNSEN-ROSCOE LAW FOR HELIOTROPIC REACTIONS

By Jacques Loeb and John H. Northrop
ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, NEW YORK CITY
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While it was customary to express animal instincts in terms of human behavior, one of us many years ago began to replace this anthropomorphic method by the objective and quantitative methods of the physicist. These methods were most easily applicable in the case of those instincts familiar to every layman in which animals were apparently attracted or repelled by light. Loeb[1] was able to express the effect of light in these cases in the following terms: Certain animals are compelled automatically to orient their body in such a way that symmetrical elements of their photosensitive surface are struck by light of the same intensity. In that case the tension and energy production in the symmetrical muscles of both sides of the body are equal and there is no reason for the animal to deviate from this direction of its motion. If, however, the symmetrical photosensitive elements (e.g., the eyes) receive unequal illumination the tension or energy production of the symmetrical muscles is no longer the same and the animal is automatically turned until its orientation is again such that symmetrical photosensitive elements receive the same amount of light.

It was obvious from the observations that this reaction was a function of the constant intensity of light and Loeb assumed that it was a photochemical effect and that the function was probably the law of Bunsen and Roscoe, whereby the effect equals the product $i\,t$, where i is the intensity of light and t the duration of illumination.[2]

The proof for the correctness of this view was furnished for the heliotropic curvatures of the hydroid *Eudendrium* by Loeb and Ewald[3] and by Loeb and Wasteneys.[4] The authors could show that if the intensity of light was lowered the time required to call forth the heliotropic curvatures of the polyps had to be increased in such a way as to keep the product $i\,t$ constant.

A second proof was furnished by Ewald[5] who showed that when constant illumination was replaced by an intermittent one the same effect could only be produced when the product of time of exposure and intensity of intermittent light was the same as that of a constant light. Ewald worked on the orientation of the eye of *Daphnia* to light. This crustacean turns its eye to the light and when the eye is under the influence of two lights of equal intensity the eye is turned in a direction at right angles to the line connecting the two lights. By keeping the one light constant, the other intermittent (through rotating a disk with a sector cut out in front of it) Ewald found that the two lights acted in an equal way when the product $i\,t$ in both cases was equal.

The experiments of *Eudendrium* as well as Ewald's experiments are tedious and it seemed desirable to have a simpler method for the verification of this law. Bradley M. Patten[6] in working on the heliotropic reactions of the larva of the blowfly (which is negatively heliotropic) determined the path of the animals under the influence of two different sources of light striking the animals simultaneously. Theoretically the animal should creep in such a direction that the intensity of illumination on both sides of its photosensitive elements should be equal, and Patten could prove that for each ratio of the two sources the path was a definite one. By rotating a wheel with a sector cut out before one source of light and cutting down the intensity of the other by a slit Patten could also show that indeed the heliotropic effect is determined by the product of intensity into duration of illumination.

"Using the apparatus described, one of the beams of light was cut down by a diaphragm and the other by an episcotister, so that the light coming from one side was a steady beam of low intensity, and that from the opposite side an intermittent beam in which bright flashes alternated with darkness. The apertures in the sector wheel were adjusted so that the amount of light from each source was equal for a unit time. It has already been established that when the larvae are subjected to equal steady beams of light from opposite directions the aggregate response is almost precisely at right angles to the line connecting the sources of light. The average angular deflection of 200 trails at equality was only 0.09°, when the degrees represented a distance of

but 1.5 mm. If the Bunsen-Roscoe law holds for the phototactic response of the larvae, they should orient perpendicularly to the rays of light when subjected to the action of steady and intermittent lights of equal energy per second. The experimental results based on 136 trails made under these conditions show an average angular deflection of but 0.07° from the perpendicular. These results seem to show that in the blowfly larva the phototactic reaction follows the Bunsen-Roscoe energy law."[7]

It seemed desirable to extend the proof for Loeb's theory of animal heliotropism and especially for the validity of the Bunsen-Roscoe energy law to other forms of animals, and we selected for the purpose the reactions of the larvae of the barnacle which were already utilized by Groom and Loeb[5] in their early experiments on the transformation of positively heliotropic animals into negative ones and vice versa.

These larvae move in a straight line towards or away from a single source of light, and when two lights of equal intensity are given they move in a line at right angles to the line connecting the two lights. These animals are small and can be obtained in large numbers. They were made to collect in the corner of a dish with a little sea water and were then sucked up into a pipette which was blackened with the exception of the opening. When such a pipette is put into a glass dish with parallel walls whose bottom is black (by putting paraffin blackened with lamp black at the bottom of the dish) the larvae will flow out in a fine stream and swim when they are positively heliotropic in a straight line towards the source of light. They thus form a rather narrow white trail on the dark bottom and it is possible to measure the angle of this trail with the line connecting the two lights. In this way in each observation the trail of thousands of individuals is measured. By using one constant and one intermittent source of light and comparing the results with those obtained by two constant lights we can test the validity of the Bunsen-Roscoe law.

The method of the experiments was as follows: *a b c d* (fig. 1) is a square dish of optical glass with blackened bottom and containing a layer of sea water. *A* and *B* are two lights, the intensity of which is determined by a Lummer-Brodhun contrast photometer. In front of each light is a screen with a round hole permitting a beam of light to go to the dish. The lights and the dish *a b c d* are so adjusted that the two beams of light striking the sides *a b* and *b c* at right angles cross each other in the middle of the dish. The light *A* is fixed while the light *B* is movable on an optical bench. The experiment is made in a dark room and the lights *A* and *B* are enclosed in a box. At the begin-

ning of the experiments the pipette is filled with a dense suspension of larvae in sea water and then put with its point touching the bottom of the dish. The animals flow out in a fine stream which is narrow at the opening of the pipette and widens slightly, owing probably to the negative stereotropism of the animals. A glass plate (fig. 2) *h i k l*, which has a strong red line *n o* and a fine parallel line *p g* (cut with a diamond), is then put on the dish and so adjusted that *p g* is in the middle of the stream *f g* of the animals. Then the angle α which *p g* makes with the perpendicular from *A* on *a b* is measured. This per-

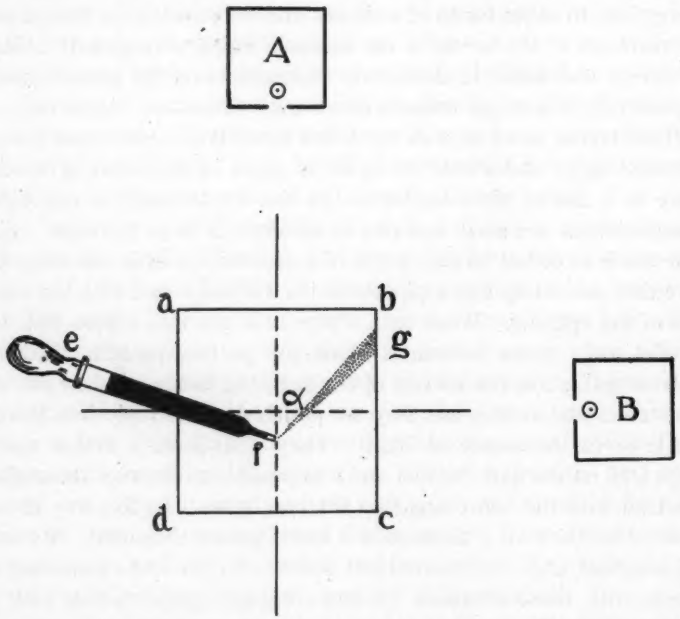

FIG. 1.

pendicular is marked in the form of a red line on the black base on which the glass vessel *a b c d* stands. The angle α is measured with a goniometer. When the lights are equal in intensity α should be 45°; if the two lights have different intensities and if *A* be the stronger light α should become smaller with increasing difference in intensity. The individual measurements vary comparatively little, as long as the difference in the intensity of the two lights is not too great; for this reason our observations do not go beyond a wider ratio of the two lights than 10:1. Table 1 gives the results. *A* is always the stronger light.

Each table is the average of from 40 to 60 individual observations, each being the average of the path of many thousands of animals.

In the next series of experiments an opaque rotating disk with one sector cut out was placed before light *B*. In one set of experiments the sector cut out was 90°. The rate of rotation (by an electric motor) was 1,500 to 2,500 revolutions per minute. The other light was constant and its position was chosen on the assumption of the validity of the Bunsen-Roscoe law for these cases. Thus when the two lights without sector were equal at a given distance of *A*, by putting the 90° sector before *B*, it was assumed that the ratio of effects would be the same as if, with constant light, *B* had been placed at the double distance and the ratio of intensities of the two lights had been 4:1. Going on such a calculation we should expect the same values for α as in table 1.

As one sees the observed values are slightly smaller but practically identical with the values obtained when the two lights are constant. The deviation is probably due to the fact that the photochemical efficiency of an intermittent light is a trifle less than that calculated on the basis of the Bunsen-Roscoe law.[9]

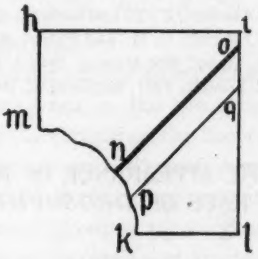

FIG. 2.

We carried out some experiments with a sector of 144°. When the efficiency of both lights was equal on the assumption of the validity of the Bunsen-Roscoe law α was found to be 44.9° (instead of 45°), and for the ratio 2:1 α was found to be 38.8°. The values are, within the limits of error, identical with the values in tables 1 and 2.

TABLE 1

	VALUE OF α FOR DIFFERENT RATIOS OF INTENSITIES OF THE TWO LIGHTS			
Ratio of the two lights	1:1	2:1	4:1	10:1
Value of α (direction of path)	45.6°	40°	34.4°	28.8°

TABLE 2

	VALUE OF α WHEN ONE LIGHT IS INTERMITTENT (90° SECTOR) AND THE OTHER CONSTANT AND THE EFFICIENCY OF THE TWO LIGHTS IS CALCULATED ON THE BASIS OF THE VALIDITY OF THE BUNSEN-ROSCOE PHOTOCHEMICAL LAW		
Ration of the two lights	1:1	2:1	4:1
Value of α	44.2°	38.3°	34.1°

Summary.—The paper gives some new quantitative experiments proving that the 'instinctive' motions of animals to light are phenomena of automatic orientation (heliotropism) and a function of the constant intensity of light; the exact expression of the function being the Bunsen-Roscoe law of photochemical action.

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THE APPEARANCE OF REVERSE MUTATIONS IN THE BAR-EYED RACE OF *DROSOPHILA* UNDER EXPERIMENTAL CONTROL

By H. G. May

DEPARTMENT OF ZOOLOGY, UNIVERSITY OF ILLINOIS

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During some experiments in selection for higher and lower facet numbers in the bar-eyed race of *Drosophila ampelophila* I obtained six full-eyed males and five heterozygous females from the stock bottles and the selected lines.

In appearance these flies could not be distinguished from normal full-eyed males and heterozygous females. Three males and three females were mated with bar-eyed flies and gave the offspring anticipated from such normal flies. In two cases the males gave only bar-eyed male offspring and heterozygous female offspring. In the third case the offspring were not examined until twenty-four days after the mating had been made and as the result of the hatching of individuals from the second generation bar-eyed females and full-eyed males were also present. The offspring of the heterozygous females in each case consisted of bar-eyed and full-eyed males and bar-eyed and heterozygous females. Some of the offspring of a full-eyed male were interbred and produced full-eyed males and bar-eyed females as well as bar-eyed males

and heterozygous females. In appearance and behavior, therefore these flies could not be distinguished from normal full-eyed males and heterozygous females.

The possibility that the flies were due to contamination is not absolutely excluded, but the probability is very low. In handling food and flies the usual precautions were used. No larvae or flies appeared in the food jars. Both vestigial-winged and long-winged races were handled, but no contamination of one with the other appeared. Three full-eyed males and one heterozygous female appeared in the vestigial race and all had vestigial wings; the others appeared in the long-winged race, and all had long wings. The fact that all females were heterozygous is a very strong argument against the probability of contamination. In case of contamination the females should, at least in the majority of cases, have been full-eyed; but no full-eyed females appeared. In the face of this evidence it is almost necessary to conclude that these flies appeared by reverse mutation and not by contamination.

The appearance of such reverse mutations can not readily be explained on the basis of the presence and absence theory nor on the theory of association and disjunction, but it is not difficult to explain on the theory of chemical change. If a chemical change in the constitution of some substance, probably in the chromosomes, produced the bar-eyed mutant, then a reversion of that chemical change would produce the original substance and so bring about the reappearance of the original character, the full eye.

The data upon which this report is based together with a more detailed discussion will be published in the near future in the report on the selection experiments.

THE PART PLAYED BY ALCYONARIA IN THE FORMATION OF SOME PACIFIC CORAL REEFS

By Lewis R. Cary

DEPARTMENT OF BIOLOGY, PRINCETON UNIVERSITY

Communicated by A. G. Mayer, June 22, 1917

Following up my studies on the coral reefs of the Tortugas Islands, in which it was found that in this particular region the alcyonaria contribute more limestone to the reefs in a given time than do the stony corals, a similar study of the coral reefs was undertaken, under the auspices of the Carnegie Institution of Washington, at the Island of Tutuila, American Samoa.

All of the coral reefs about Tutuila are fringing reefs, with the exception of the large reef at Nueli (Blacks Bay on the charts), which appears to be changing from a fringing into a barrier reef. Along most of the north shore the reefs are restricted to the bays, or harbors, while on the south side of the island the reefs are continuous from bay to bay around many of the headlands.

In Pago Pago harbor, which is bordered with coral reefs broken only where one of the numerous streams has its entrance, there exists all of the possible conditions of reef environment varying from those at the entrance of the harbor where the surf beats incessantly to those at its inner end where, even in severe storms, the water is only slightly agitated. Marked gradations in the salinity of the water and in the amount of sediment which it bears are also found at different points within this area so that the relationship of reef building organisms to these factors can be readily observed.

Six species only of alcyonaria were found on the reefs at Tutuila. Of this number two occur so rarely that they are unimportant factors as reef builders. All six species belong to the *Alcyonaceae*.

Two of the more abundant species contribute to reef formation only through the setting free of their spicules at the death of the colony. The others, *Alcyoneum rigidum* and *A. confertum*, form at the base of the colony a corallium-like mass of limestone composed of closely cemented spicules, upon which the living tissues are bourn. This rock is continuously added to as the colony grows outward and upward, the living tissues disintegrating about its base as expansion takes place. In this way heads composed of spicule rock are formed which extend to a height of 4 feet (up to low tide mark) above the general reef flat, and which have a circumference as great as 20 feet.

The distribution of the alcyonaria on the Pago Pago reefs depends on a number of factors. Very few specimens are found on the horizontal surfaces of the exposed reefs. On the nearly vertical faces of these reefs, however, *Alcyonium rigidum* often covers large areas forming a nearly continuous carpet. This species occurs on the faces and in the deeper holes of practically all of the reefs about Tutuila, but on the horizontal surfaces of only those reefs which while protected from heavy breakers, are traversed by strong currents which provide for good aeration, normal temperature of the water and against the silting up of the colonies.

A. confertum, which is next in importance as a reef builder, is the most resistant of the four species and is consequently the most widely distributed.

A. glaucum requires much the same environmental conditions as *A.*

rigidum but is commonly found in slightly less favorable conditions than the latter by which it is, on account of its habits of growth, easily crowded from the most favorable locations.

The fourth species *A. flexilae* is by far the most delicately branched and is also incapable of retracting its branches. It is consequently restricted to very quiet waters in the most protected locations on the reefs.

To determine the proportion of alcyonaria in different locations on the Pago Pago reefs clearly marked lines were run across a number of the reefs from the shore to their outer edges. Along these lines squares 25 feet on a side were laid off and the area occupied by alcyonaria esti-

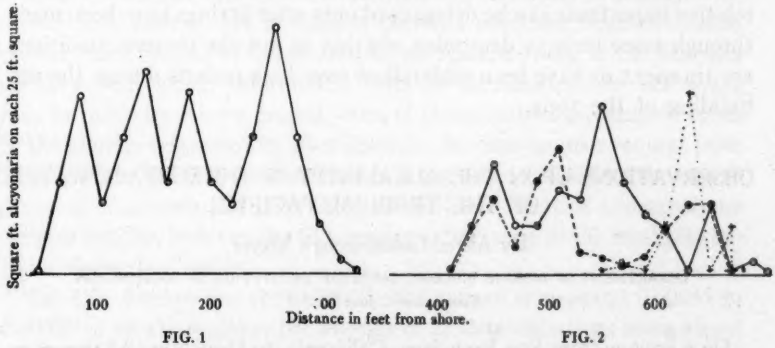

FIG. 1 FIG. 2

FIG. 1. Showing the distribution of the alcyonaria across the Utelei reef Pago Pago harbor, Samoa. The figures along the ordinate represent the distance in feet from shore, those along the abscissa the area in square feet covered by alcyonaria on each square the sides of which were 25 feet in length.

FIG. 2. Showing the distribution of three species of alcyonaria along a line the total alcyonaria of which is shown in figure 1.

Distribution as shown in the previous figure. Alcyonium glaucum, o————; Alcyonium confertum, ● - - - - -; Alcyonium rigidum, + ...

mated for each square. Figure 1 shows the conditions on a reef along the south side of a cove at Utellei village which is situated on the west side of Pago Pago harbor about three-quarters of a mile from its entrance.

On account of the configuration of the shore line at this place a strong current sets across the reef area traversed by the outer half of this line, while over the inner portion the currents are very weak. The depth at extreme low tide varies from 6 to 15 inches over all of this reef except the lithothamnuium ridge which is exposed for a width of from 50 to 75 feet.

Figure 2 shows the area occupied by each one of the three species occurring along this line. The thickness of the rock formed from spicules

over these areas varies from a mere veneer to at least 2 feet. Along the outer vertical face of the reef on the opposite (north) side of this same cove many barren areas were found to be covered with a surface layer of spicule rock from 1 to 12 inches in thickness. This layer extends back into many subterranean caverns in the reef for a distance of several feet, and when added to the area of the reef face now covered with living alcyonaria constitutes an almost complete covering of spicule rock over the entire reef face for more than one-third of a mile from the head of the cove.

While these observations have made it clear that on certain of the pacific reefs the alcyonaria are important coral forming agents their relative importance can be determined only after borings have been made through some reefs to determine whether or not the present conditions are transient or have been maintained over long periods during the upbuilding of the reefs.

OBSERVATIONS UPON THE ALKALINITY OF THE SURFACE WATER OF THE TROPICAL PACIFIC

By Alfred Goldsborough Mayer

DEPARTMENT OF MARINE BIOLOGY, CARNEGIE INSTITUTION OF WASHINGTON

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On a voyage from San Francisco, California, to Honolulu and thence to Pago Pago, Samoa; and also upon the return over the same route, we made daily observations of the hydrogen-ion concentration of the surface water, using for this purpose a set of thymolsulphonephthalein tubes standardized and prepared by Prof. J. F. McClendon, and kindly presented to us for this purpose.

It was found that in the mid-Pacific, N.N.E. of Samoa, the surface water at or near the equator was cooler, and less alkaline than 5°–10° north or south of this region. This fact will appear upon inspection of the tables at the end of this paper. It seems that the water of the equator at 24°9 C. is so low in alkalinity as to be comparable in this respect with the water of only 15°C. about 300 miles off the mouth of San Francisco Harbor, California.

The low alkalinity of the water near the equator was usually although not invariably associated with a decided easterly set opposite in direction to the prevailing westerly surface drift of the tropical Pacific.

This suggests that counter currents at the surface in the tropical Pacific may be regions wherein the cold bottom water is rising to the surface; and that this cold water has not yet had time to come into

equilibrium with the carbon dioxide of the atmosphere, and thus still retains some of the relative acidity associated with its former low temperature.

Similarly, we would expect cold currents drifting into warmer regions to retain their relative acidity to a greater degree than is warranted by their augmenting temperature; and this expectation appeared to be justified by the very low alkalinity of 0.141×10^{-7} shown by the water at 10°.5 C., 54 miles W.S.W. of Golden Gate, San Francisco, on May 1, 1917.

No conclusions should be drawn from such meagre observations, but if future studies should demonstrate that low alkalinity is usually associated with easterly set of surface currents over the tropical oceans, the fact may become of importance to navigation owing to the ease and rapidity with which colorimetric tests of the alkalinity of sea water may be made by using a graded series of thymolsulphonephthalein tubes in the manner suggested by McClendon. In response to a request from Professor McClendon, tests were made of the carbon dioxide of the atmosphere at noon each day, but these showed that there is apparently no definite relation between the CO_2 tension of the air and the local alkalinity of the surface water.

The CO_2 tension was very variable and ranged from about 0.00045 to 0.00025 of an atmosphere, the average of 22 determinations being about 0.00035. There is also no definite relation between the salinity and the hydrogen-ion concentration of the ocean water, as will appear from the following tables.

The cold current which moves southward along the coast of California, is of low salinity being about 33.6 or 33.7 on an average whereas the salinity of the water between 1000 miles off the Californian coast and the Hawaiian Islands is about 35.

An elaborate study of the salinity and temperature of the water off the California coast has been made by George F. McEwen, *University of California Publications, Zoology*, **15**, 1916, (255–356, Plates 1–38), and the presence of an upwelling of cold water from the depths is clearly indicated along the California Coast as a result of studies by Michael and McEwen.

TABLE 1

TEMPERATURE AND ALKALINITY OF SEA WATER AT THE SURFACE FROM SAN FRANCISCO, CALIFORNIA, TO HONOLULU; AND THENCE TO PAGO PAGO, SAMOA, FEBRUARY 21 TO MARCH 5, 1917, ON S. S. *Sierra*, CAPTAIN JOHN J. K. KOUGHAN

DATE 1917	TEMPERATURE OF AIR °C.	TEMPERATURE OF SEA WATER, °C.	HYDROGEN-ION CONCENTRATION OF SEA WATER	P_H OF SEA WATER	LATITUDE	LONGITUDE	MILES FROM PORT	BAROMETER IN INCHES	REMARKS
San Francisco to Honolulu									
February 21, noon	16°.6	12°.3	0.89×10^{-8}	8.05	36° 05′ N.	128° 38′ W.	302	29.79	Wind from west; rough sea
February 22, noon	15°.4	15°.4	0.676×10^{-8}	8.17	33° 32′ N.	135° 09′ W.	657	29.88	Rough; overcast. Wind from S–S. E.
February 23, noon	16°.5	17°.6	0.63×10^{-8}	8.2	30° 53′ N.	140° 53′ W.	988	29.53	Squally; rain, rough. Wind from W.N.W.
February 24, noon	18°.3	20°.1	0.589×10^{-8}	8.23	27° 49′ N.	146° 28′ W.	1334	30.01	Overcast, N.N.W. wind; moderate sea
February 25, noon	21°.2	21°.6	0.563×10^{-8}	8.25	24° 22′ N.	152° 19′ W.	1712	30.05	S.W. breeze; overcast, moderate sea
February 26, 10 a.m.	23°.4	23°.6	0.563×10^{-8}	8.25	21° 25′ N.	157° 25′ W.	2050		Clear; nearly calm; breeze from S.E., 30 miles off Honolulu
From Honolulu to Pago Pago, Samoa									
February 27, noon	24°.7	24°.2	0.563×10^{-8}	8.25	17° 52′ N.	159° 13′ W.	220	30.04	Clear, light trade wind from N.N.E.
February 28, noon	25°.5	25°.4	0.563×10^{-8}	8.25	12° 10′ N.	161° 17′ W.	588	29.97	Clear. Strong E.N.E. trade wind
March 1, noon	26°.3	26°.1	0.589×10^{-8}	8.23	6° 35′ N.	163° 21′ W.	940	29.84	Clear; rough; wind from E.N.E.
March 1, 5:20 p.m.	26°.2	25°.9	0.63×10^{-8}	8.2	5° 13′ N.	163° 40′ W.	1021		Strong current to east. Wind from N.E.
March 2, noon	24°.7	24°.2	0.676×10^{-8}	8.17	1° 07′ N.	165° 30′ W.	1293	29.78	Current to the N.W. all day; fair E. breeze; smooth.
March 2, 4.45 p.m.	24°.5	24°.85	0.656×10^{-8}	8.18	Equator	165° 50′ W.	1364		Current to the N.W. all day; fair E. breeze; smooth.
March 3, noon	26°.3	26°.4	0.63×10^{-8}	8.2	4° 35′ S.	167° 24′ W.	1653	29.79	Light breeze from east; clear
March 3, 5 p.m.	26°.4	26°.8	0.595×10^{-8}	8.225	5° 49′ S.	167° 45′ W.	1728		Light breeze from east; clear
March 4, noon	27°.4	28°.0	0.563×10^{-8}	8.25	10° 14′ S.	169° 14′ W.	2010	29.81	Clear, light breeze from east
March 4, 5 p.m.	27°.4	27°.9	0.563×10^{-8}	8.25	11° 29′ S.	169° 36′ W.	2085		Clear, light breeze from east
March 5, 6 a.m.	26°.8	27°.3	0.563×10^{-8}	8.25	14° 09′ S.	170° 31′ W.	2262		About 10 miles N. of Tutuila, Samoa

TABLE 2

TEMPERATURE, ALKALINITY, AND SALINITY OF SEA WATER AT THE SURFACE FROM PAGO PAGO, SAMOA, TO HONOLULU AND THENCE TO SAN FRANCISCO, CALIFORNIA, APRIL 19 TO MAY 1, 1917, ON S.S. *Ventura*, CAPTAIN J. H. DAWSON

DATE, 1917	TEMPERATURE OF AIR, °C.	TEMPERATURE OF SEA, °C.	HYDROGEN-ION CONCENTRATION OF SEA WATER	PH OF SEA WATER	SALINITY OF SEA WATER	LATITUDE	LONGITUDE	MILES FROM NEAREST PORT	BAROMETER	DIRECTION OF CURRENT	WEATHER
Pago Pago, Samoa, to Honolulu, Hawaiian Islands											
April 19, noon	25°.4	27°.8	0.575×10^{-8}	8.24	35.10	10° 15′ S.	169° 03′ W.	262	29.87		Light breeze from N.E.; showers. Raining when sample was taken
April 20, noon	26°.95	26°.75	0.708×10^{-8}	8.15	35.41	5° 10′ S.	167° 00′ W.	591	29.84	To the east	N.E. breeze; clear weather
April 21, noon	25°.4	24°.95	0.759×10^{-8}	8.12	35.26	Equator	165° 05′ W.	919	29.80	Strong current to the east	E.N.E. breeze; clear weather
April 22, noon	26°.4	25°.9	0.795×10^{-8}	8.1	35.05	5° 42′ N.	163° 12′ W.	1281	29.82	No current	Strong breeze from N.E.; moderate sea
April 23, noon	25°.4	25°.35	0.603×10^{-8}	8.22	34.58	11° 19′ N.	161° 05′ W.	1641	29.90	No current	Moderate breeze from N.E.; clear
April 23, 5.00 p.m.	25°.3	25°.5	0.588×10^{-8}	8.23		12° 29′ N.	160° 39′ W.	1723		No current	Moderate breeze from N.E.; clear
April 24, 7.30 a.m.	24°.7	24°.55	0.588×10^{-8}	8.23+		15° 58′ N.	159° 46′ W.	1932		Set to the west	Breeze from N.E.; clear; moderate sea
April 24, noon	24°.2	24°.5	0.617×10^{-8}	8.21	34.58	17° 03′ N′.	159° 23′ W.	1999	29.96	To the east	Clear E.N.E. breeze; moderate current
April 24, 5.30 p.m.	23°.5	24°.05	0.582×10^{-8}	8.235		18° 33′ N.	159° 00′ W.	2081		Set to the west	Clear; breeze from the east
April 25, 5.00 a.m.	21°.1	23°.75	0.617×10^{-8}	8.21				15 miles S. of Honolulu		Set strongly to the east	Calm, clear all day

TABLE 2—*Continued*

DATE, 1917	TEMPERATURE OF AIR, °C.	TEMPERATURE OF SEA, °C.	HYDROGEN-ION CONCENTRATION OF SEA WATER	PH OF SEA WATER	SALINITY OF SEA WATER	LATITUDE	LONGITUDE	MILES FROM NEAREST PORT	BAROMETER	DIRECTION OF CURRENT	WEATHER
Honolulu to San Francisco, California											
April 25, 6 30 p.m.	22°.4	23°.9	0.63×10^{-8}	8.2	34.94	5 miles off the S.E. Point of Oahu			29.93	Easterly set; current moving N.E.?	Calm, clear all day
April 26, noon	22°.6	25°.6	0.582×10^{-8}	8.21	34.79	23° 51′ N.	153° 44′ W.	281	29.94	Easterly set; current moving N.E.?	Breeze from the east; clear smooth sea
April 27, noon	21°.9	21°.6	0.588×10^{-8}	8.23+	35.23	27° 18′ N.	147° 52′ W.	662	29.95	Current southerly	Breeze from the east; overcast; moderate sea
April 28, noon	19°.4	19°.8	0.63×10^{-8}	8.2	35.05	30° 29′ N.	141° 50′ W.	1033	30.02	No current	Breeze from the east; clear; moderate sea
April 29, noon	16°.6	16°.6	0.795×10^{-8}	8.1	33.89	33° 39′ N.	135° 34′ W.	1405	30.13	Northerly current	Clear, nearly calm
April 30, noon	16°.1	14°.3	0.795×10^{-8}	8.1	33.17	36° 00′ N.	128° 59′ W.	1760	30.15	No current	Overcast. No rain. Nearly calm. Water blue as in mid-Pacific
May 1, 7.00 a.m.	12°.7	10°.5	0.141×10^{-7}	7.85	33.33	54 miles off Golden Gate, San Francisco Harbor		2036		Southerly current	Calm; clear; slight breeze from the west. Water dark greenish-brown to olive.

THE EFFECT OF TEMPERATURE ON LINKAGE IN THE SECOND CHROMOSOME OF DROSOPHILA

By Harold H. Plough

ZOOLOGICAL LABORATORY, COLUMBIA UNIVERSITY

Communicated by T. H. Morgan, July 5, 1917

Some recent data have shown that certain influences affect the percentage of crossing over. Bridges[1] (1915) noted that the age of the mother altered the result in the second chromosome, and Sturtevant[2] (1917) has recently discovered no less than three definite Mendelian factors which influence the strength of linkage in parts of the second and of the third chromosomes. For two years I have been studying the effect of changes in the environment on the percentage of crossing over in *Drosophila melanogaster* (*ampelophila*). It has been found that very striking effects are produced by differences in temperature for the second chromosome. A full report of this work will appear in a forthcoming number of the *Journal of Experimental Zoölogy*.

Tests of the effect of temperature on the percentage of crossing over were made in the following way. Virgin females from the stock collected originally at Falmouth, Mass., were mated to males homozygous for the second chromosome factors for black body color, purple eyes and curved wings. The pairs were placed successively in two or more sets of bottles for three or four days each. The bottles of the first set were kept at room temperature—about 22°C—and each of the other sets at one of the temperatures to be tested. The normal females heterozygous for black purple curved which hatched from each set were then back crossed to males of the original mutant stock and the offspring allowed to hatch at room temperature. The offspring (F_2) of the back cross show the genetic constitution of the (F_1) eggs, and enable one to calculate the percentage of crossing over between black and purple, and purple and curved. The percentages for the shorter region—black to purple—from a number of experiments involving more than 35,000 flies are shown in the curve given in figure 1. The value at 22°C is the average of the controls for all of the different sets. At lower and higher temperatures—5°C. and 35°C.—no fertile offspring hatched.

The curve is of considerable interest since it shows that both high and low temperatures produce an *increase* in the percentage of crossing over, i.e., a reduction in the strength of linkage. It is plain that the process does not follow van't Hoff's law, as do most physiological processes.[3] The phenomenon therefore involves apparently some change in the physical state of the colloidal substratum of the cells.

Further investigation has demonstrated that the increase in the percentage of crossing over due to high or low temperature applied during the development of the female parent is maintained for only six or seven days after she begins to lay. At the end of this period the percentage drops to the same level as the control. It has also been found that the high or low temperature can be applied to adult females with similar results. After the flies are exposed to the new temperature, an interval elapses during which 225 to 275 eggs are laid which do not show the effect of the new temperature. The percentage then jumps suddenly to the high point where it remains for approximately the length of time of the exposure. A curve illustrating this point is shown in figure 2. The mothers of both series were sisters hatched at room temperature.

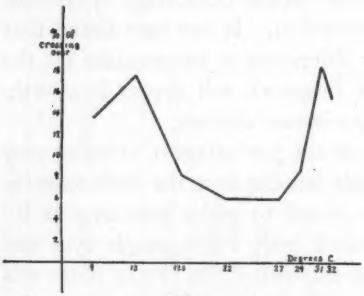

FIG. 1

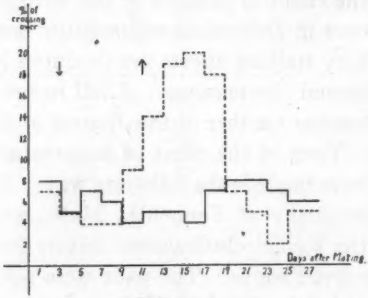

FIG. 2

They were mated and placed in phials which were changed regularly at two day intervals. From the third to the eleventh day the pairs of one series were exposed to a temperature of 31.5°C while the others were continued at room temperature. The percentage of crossing over for the black to purple region is shown in the curve. After an interval of eight days following the beginning of the treatment (i.e., beginning on the same day that the flies were returned to normal temperature) the treated series showed an increase of more than 100% in the amount of crossing over among their offspring. This high ratio was maintained for eight days, after which it returned at once to the control value.

The facts apparently indicate that temperature affects the amount of crossing over at a definite stage in the oogenesis. Exposures to high temperatures for one, two or four day periods make it appear that a consecutive exposure of nearly two days is required to produce any effect at all. Cytological examination has shown that shortly after hatching about 140 eggs have usually passed the last oogonial division. Controls show that eggs are laid at the rate of about 50 a day or 100

in two days. This number of eggs therefore has not received the exposure necessary to produce the change in crossing over. The culmination of the two days exposure is to be expected in those eggs so situated that 125 to 175 eggs will be laid before them. Such an interpretation makes it extremely likely that the change in the amount of crossing over is finally affected in the earliest oocytes, that is, at the beginning of the growth period. The above evidence on the time of applying the new temperature and the time when the change in crossing over occurs, suggests that the crossing over process takes place in the stage when the chromosomes of Drosophila are known to be finely drawn out threads.

The decrease in the strength of linkage caused by temperature in no way weakens the chromosome interpretation of linkage. It rather adds to it considerable support, for it localizes the process of crossing over at a period in oogenesis when twisting between homologous threads seems possible. The evidence positively establishes the fact that crossing over does not take place during the early oogonial divisions, and makes it extremely improbable that it occurs at so late a stage in the growth period as the thick thread stage favored by Janssens as the chiasmatype.

[1] Bridges, C. B., *J. Exp. Zoöl., Wistar Inst., Philadelphia*, 19, No. 1, July, 1915.
[2] Sturtevant, A. H., these PROCEEDINGS, 3, 1917, (555–558).
[3] Cf. Snyder, C. D., *Amer. J. Physiol.*, 22, 1908, (309).

GENETIC FACTORS AFFECTING THE STRENGTH OF LINKAGE IN DROSOPHILA

By A. H. Sturtevant

ZOOLOGICAL LABORATORY, COLUMBIA UNIVERSITY

Communicated by T. H. Morgan, July 5, 1917

In September, 1913, a wild female Drosophila of a stock from Liverpool, Nova Scotia, was crossed to a male bearing the second chromosome mutant characters vestigial and speck. A single daughter of this mating was tested, and gave no crossovers among 99 offspring, though vestigial and speck usually show about 37% crossing over. This strain has since been bred in very large numbers, and the experiments are being continued; but it has seemed advisable to report briefly on some of the results obtained.[1]

It has become clear that the original result was due to something in the second chromosome derived from the Nova Scotia female. Two of her granddaughters and all of her later descendants that were known, from linkage, to have received the second chromosome in question gave

similar results; but those descendants known not to have received it gave the 'usual' result. This was true whether the chromosome came from the mother (as above) or from the father. And when other second chromosome genes were substituted for vestigial and speck, unusual ratios still appeared; but for any combination the result was relatively constant, and the combined 'unusual' results give as consistent a scheme as the 'usual' results. The first column of table 1 shows the percentage of crossing over in the ordinary females for various combinations of second chromosome genes.[2] The second column gives similar data for tests of females that carry a Nova Scotia chromosome. Figures 1 and 2 are chromosome maps constructed on the basis of these two columns.

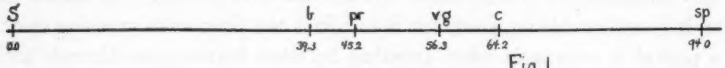

Fig. 1

Fig. 2

Fig. 3

Fig. 4

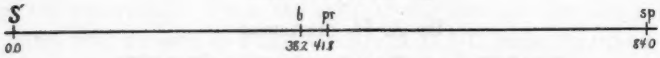

Fig. 5

Fig. 6

A large number of these experiments have been made with females having one Nova Scotia chromosome, and its mate bearing the mutant genes black, purple, and curved. Numerous tests have been made in order to determine the nature of the crossovers produced. It has been found that those crossovers that receive the part of the original Nova Scotia chromosome lying to the left of the purple locus still give unusual results and transmit the peculiarity to all of their descendants that receive this piece. The results produced by such females are not, however, the same as those produced when all the Nova Scotia chromosome

is present, as is shown in column 3 of table 1 and in figure 3. When the other piece of the Nova Scotia chromosome, lying to the right of purple (and, in many experiments, that part of it that is also to the left of speck) is tested, a still different result is obtained, as shown in column 4 and figure 4.

TABLE 1

GENES	PERCENTAGE OF CROSSING OVER					
	Normal	$\frac{C_{II\,l}\ C_{II\,r}}{}$	$\frac{C_{II\,l}}{}$	$\frac{C_{II\,r}}{}$	$\frac{C_{II\,r}}{C_{II\,r}}$	$\frac{C_{II\,l}\ C_{II\,r}}{C_{II\,r}}$
Star black	39.3	0.0	0.0	42.4	38.2	0.3*
Star purple	40.2	0.0	×	45.4	40.6	0.3*
Star curved	46.5	×	25.9	47.3	×	×
Star speck	48.3	0.4	49.0	46.0	49.0	47.4
Black purple	5.9	0.2	0.4	5.8	3.6	0.1
Black vestigial	16.9	1.2	×	8.9	×	×
Black curved	22.7	1.3	25.6	7.5	×	×
Black speck	49.3	1.1	48.8	9.3	43.5	47.0
Purple vestigial	11.1	1.2	×	0.6	×	×
Purple curved	19.0	1.1	20.5	1.7	×	×
Purple speck	46.5	1.2	47.4	2.8	42.2	47.4
Vestigial speck	36.7	0.2	×	0.0	×	×
Curved speck	29.8	0.1	35.2	0.2	×	×
†Total length	94.0	1.4	56.1	50.1	84.0	47.8

* These few (6) crossovers are doubtful. None of them were tested; and there is apt to be a small percentage of error in classifying Star flies.

† Calculated as Star black + black purple + purple curved + purple speck in all but the last two columns, where purple speck is used. In no case further corrected for double crossing over.

It follows from these results that the original Nova Scotia chromosome contained at least two factors causing reduced crossing over, and each affecting chiefly the region in which it lies. We may call these two factors '$C_{II\,l}$' and '$C_{II\,r}$' (C for crossing over, after Muller,[3] II to distinguish them from similar factors affecting other chromosomes, *l* and *r* for left hand and right hand).

By appropriate matings it has been possible to obtain females homozygous for $C_{II\,r}$, and a surprising result has been observed: the effect produced by $C_{II\,r}$ when heterozygous disappears when it becomes homozygous (see columns 5 and 6, figures 5 and 6). There can be no doubt of this result, as it has been obtained repeatedly, and has often been checked by tests of the offspring. It has also been paralleled more recently by results obtained by Muller[3] (1916) and by me[4] with C_{III}. Similar tests of homozygous $C_{II\,l}$ have not been possible since no chromo-

some has yet been obtained that contains both that factor and any mutant factor within its "sphere of influence."

Backcross tests have shown that males of all the above types with respect to C_{III} and C_{IIr} resemble "normal" males in giving no crossovers at all.

Included in the above tables are a considerable number of data involving three or more loci at once; and these agree with the table in showing clearly that the linear order of the factors established for the usual second chromosome is unchanged by the factors under discussion. The amount of crossing over is altered, often markedly, and not usually proportionately in different regions; but the factors keep their same sequence. This result serves to emphasize the importance of considering the distances on chromosome maps as only diagrammatic, not as representing actually proportionate distances between the genes, although actual distance is evidently an important factor influencing the end result. It does not, I think, in any way weaken the case for the chromosome hypothesis, but merely shows, together with the results of Bridges[5] (1915) and Plough[6] (1917), that any chromosome map is available for purposes of numerical prediction only when the conditions under which it was made are duplicated.

[1] Some of the early results were reported at the 1913 meeting of the American Naturalists, and brief references have been published by me (1915) and by Muller (1916).

[2] Much of this data has not hitherto been published. It has been collected mainly by Dr. C. B. Bridges, to whom I am indebted for permission to use it.

[3] Muller, H. J., *Amer. Nat., Lancaster, Pa.*, **50**, 1916, (193, 284, 350, 421).

[4] Sturtevant, A. H., *Zs. Abst. Vererb.*, **13**, 1915, (234).

[5] Bridges, C. B., *J. Exp. Zool., Wistar Inst. Philadelphia*, **19**, 1915, (1).

[6] Plough, H. H., these PROCEEDINGS, **3**, 1917, (553–555).

FURTHER EVIDENCE ON THE CONCENTRATION OF THE STARS TOWARD THE GALAXY

By Frederick H. Seares

MOUNT WILSON SOLAR OBSERVATORY, CARNEGIE INSTITUTION OF WASHINGTON

Communicated by G. E. Hale, July 9, 1917

In a previous communication[1] attention was directed to the striking difference in the results for the distribution of the stars with respect to the galactic plane found by Kapteyn[2] and by Chapman and Melotte.[3] An analysis of the counts of stars on photographs of 88 Selected Areas, made at Mount Wilson with the 60-inch reflector, gave preliminary values for the variation in the totals to magnitude 17.5 which agree well with those of Kapteyn.

Further confirmatory evidence of the large value of the galactic condensation for the faint stars, which is so striking a feature of Kapteyn's conclusions, is available from two different sources. The first is a series of counts made at Groningen on photographs of 54 Selected Areas taken with the Bruce telescope of the Harvard station at Arequipa in Peru. The results for these including 127,315 stars, are given by Kapteyn in his *First and Second Reports on the Progress of the Plan of Selected Areas.*[4] The second source of data for a comparison is the collection of counts recently published by Turner for nearly 600,000 stars in zones of the *Astrographic Catalogue.*[5]

The durchmusterung photographs of the southern Selected Areas extend from $+62°$ to $-76°$ galactic latitude, and are well distributed throughout this interval. The exposure time was two hours. We assume that the different plates are comparable, in limiting magnitude, and a reference to Professor Kapteyn's tabulation[6] indicates that the agreement in this particular is satisfactory. The calculated limits of brightness given by him show considerable irregularity, but it should be noted that these have been derived from the observed density in each field, and are thus affected by local variations in the distribution of the stars, as well as by changes in atmospheric transparency and in the photographic conditions of exposure and development. For example, area No. 110, galactic latitude $+1°$, lies between the two branches of the Milky Way, and is known to include an abnormally small number of stars. This accounts for the unusually bright limit of 13.2 given by Kapteyn.

The photographs of areas in southern latitudes are richer in stars than those north of the Galaxy; but since the evidence from other sources as to the reality of this difference is conflicting, no distinction has been made between northern and southern latitudes in forming the mean curve connecting latitude with stellar density (number of stars per square degree to the limiting magnitude m, denoted by N_m).

After the counts had been arranged in the order of increasing latitude, overlapping means for groups of ten areas were formed, with the results shown in the first two columns of table 1. These define a smooth curve whose ordinates and corresponding abscissae for equidistant intervals are in the third and fourth columns of the table. The value in parentheses is an extrapolation. The fifth column contains the densities from Kapteyn's table in *Groningen Publication*, No. 18, p. 54, for magnitude 16.0, which is adopted as the mean limit for the whole series of plates. In the column following are the densities from the Mount Wilson photographs of 88 northern Selected Areas. These are the values given in

these PROCEEDINGS, 3, 1917, 219, after the application of a correction of −0.10 to the logarithms to reduce them to the limiting magnitude of the durchmusterung plates.

The significant feature of the table is the relation between the three series of results shown by the differences in the last two columns. These reveal no important systematic effect and show that the increase in stellar density with decreasing latitude is substantially the same for all three investigations. The differences MW–DM are noteworthy in that all of the Mount Wilson photographs are of regions on or north of the celestial equator, while the durchmusterung areas are on or south of the equator, with only seven regions in common.

The average value for the ratio of the number of stars at 5° latitude to the number at 80° is 23, with deviations of −2, +4, and −2 for DM, Kapteyn, and MW, respectively. This result refers to magnitude 16.0 on the scale of *Groningen Publication* No. 18. On the international photographic scale the limit would be approximately 17.0.

The counts for the Astrographic zones, which constitute a very important collection of data, have been discussed with detail in an article that will appear in the *Astrophysical Journal*. The salient features only need be touched upon here. The zones are ten in number, each 2° wide, and well distributed in declination from +62° to −65°. The counts extend throughout the entire 24 hours of right ascension, so that each zone includes a wide range of galactic latitude. We have here, for each hour of right ascension, not only the total number of stars to the faintest limit of the *Catalogue*, but also the totals to at least one, and usually two, other limits from one to three magnitudes brighter. We assume that each limit is constant for any given zone; although there are obvious irregularities, their influence is pretty thoroughly eliminated by the method of discussion, and it is improbable that the mean distribution is affected to any important degree.

A curve connecting latitude and density was drawn, just as in the case of the durchmusterung counts above, for each separate limit of each zone. From these curves were read the stellar densities for each 10° latitude. With these and their respective latitudes as arguments, corresponding magnitudes were interpolated from Kapteyn's distribution table in *Groningen Publication* No. 18. The mean of the magnitudes thus found for any curve was adopted as the limiting magnitude for that curve and for the series of counts to which it corresponds. The process is exactly that described in these PROCEEDINGS, 3, 1917, 217, and there used for the determination of the limiting magnitude, on the scale of Kapteyn's table, of the Mount Wilson photographs of the Selected Areas.

The next step involved the segregation of the data for equidistant values of galactic latitude. The 0° ordinate for each of the original curves was plotted against the limiting magnitude just found for the curve to which it belongs. These points define a new curve expressing the variation of stellar density with magnitude for regions in 0° latitude. Similar curves were also derived for 10°, 20°, etc., by plotting the appropriate ordinates of the original curves against their limiting magnitudes

TABLE 1

COMPARISON OF DURCHMUSTERUNG RESULTS WITH KAPTEYN AND MOUNT WILSON

MEAN LATITUDE	OBSERVED LOG N_m	GALACTIC LATITUDE	LOG N_m			KAPTEYN MINUS DM	MW MINUS DM
			DM	Kapteyn	MW		
3°	3.99	5°	3.97	4.04	4.03	+0.07	+0.05
10	3.90	15	3.79	3.74	3.76	−0.05	−0.03
16	3.75	25	3.50	3.47	3.43	−0.03	−0.07
23	3.63	35	3.22	3.23	3.16	+0.01	−0.06
30	3.32	45	3.00	3.04	3.00	+0.04	0.00
37	3.17	55	2.84	2.89	2.88	+0.05	+0.04
47	2.98	65	2.74	2.74	2.79	0.00	+0.05
60	2.79	80	(2.65)	2.60	2.69	(−0.05)	(+0.04)

TABLE 2

DIFFERENCES IN LOG N_m FROM ASTROGRAPHIC ZONES AND FROM KAPTEYN'S TABLE OF DISTRIBUTION

(Unit = 0.01)

MAGNITUDE	GALACTIC LATITUDE								
	0°	10°	20°	30°	40°	50°	60°	70°	80°
8.5	−3	0	0	+2	+2	+1	+1	+1	0
9.0	−3	0	0	+1	0	−2	−2	−1	−2
9.5	−1	+1	+3	+2	0	−3	−3	−3	−1
10.0	0	+1	+3	+3	0	−2	−3	−2	−1
10.5	−1	+1	+4	+3	0	−2	−4	−2	+1
11.0	−3	0	+4	+3	−1	−2	−3	−2	−1
11.5	−3	−1	+4	+4	+1	−1	−1	0	−1
12.0	−4	−1	+3	+4	+1	0	0	+1	−2
12.5	−5	−1	+4	+5	+3	+2	+2	+1	−1

as before. From the new curves were read the densities corresponding to each half-magnitude interval from 8.5 to 12.5. The results, when tabulated, constitute a distribution table analogous to that of Kapteyn, though restricted in its range of brightness.

Our interest is naturally in the agreement of these two tables. Their differences (Astrographic zones *minus* Kapteyn), in units of the second decimal, are shown in table 2. Though more or less systematic, the

deviations are very small—in most cases within the uncertainty which necessarily affects the discussion of the data. To this extent, therefore, we may look upon them as supplying a very satisfactory confirmation of Kapteyn's results. This fact is further illustrated by the following series of values for the galactic condensation (ratio of number of stars at 5° to number at 80°).

Limiting Magnitude	8.5	9.5	10.5	11.5	12.5	16.0
Kapteyn	2.6	3.1	3.8	4.9	6.7	27
Astrographic Zones	2.4	3.2	3.8	4.7	6.2	....
Arequipa, Selected Areas	...	....	....	....	....	21
Mt. Wilson, Selected Areas	...	....	....	....	....	21

It is important to note that the use of Kapteyn's density table for the determination of the limiting magnitudes of the counts has not artificially forced an agreement with his values of the galactic concentration. The use of a limit thus derived for any zone in no wise affects the rate at which the density observed within that zone increases with decreasing latitude. The results are referred to Kapteyn's scale of magnitudes, but this influences only indirectly the value of the condensation for any specified limit.

A comparison of the counts for the different zones with the mean distribution table whose derivation has been outlined reveals large deviations in individual cases. To what extent these represent local variations in stellar density cannot now be determined. Professor Turner has been led to believe[7] that the Astrographic data give evidence of a spiral of obscuration encircling the sky, in which the ratio of the number of faint stars to bright stars is abnormally low. But his discussion seems not to include the influence of the increase in galactic condensation with increasing magnitude, which appears so clearly in the numbers appended to the preceding paragraph. When this has been duly allowed for, the fluctuations in the ratio of faint stars to bright stars assume an accidental character; doubtless they correspond in part to actual variations in density, but differences in observing conditions must also have contributed much in producing the irregularities.

[1] Seares, F. H., these PROCEEDINGS, **3**, 1917, (217–222).

[2] Kapteyn, J. C., *Groningen, Pub. Astr. Lab.*, No. 18, 1908, (1–54).

[3] Chapman, B. A., and Melotte, P. J., *London, Mem. R. Astr. Soc.*, **60**, 1914, (145–173).

[4] Published by the Astronomical Laboratory at Groningen, 1911, (1–34).

[5] Turner, H. H., Numerous articles in *London, Mon. Not. R. Astr. Soc.*, **72, 75, 76, 77**, 1909–1916.

[6] Kapteyn, J. C., *First and Second Reports, Groningen*, 1911, (1–34), p. 15.

[7] Turner, H. H., London, *Mon. Not. R. Astr. Soc.*, **76**, 1915, (149–157), p. 152.

THEORETICAL RELATIONS IN THE INTERFEROMETRY OF SMALL ANGLES[1]

By Carl Barus

DEPARTMENT OF PHYSICS, BROWN UNIVERSITY[2]

Communicated July 25, 1917

In addition to the sides of the ray parallelogram (base, b) and the radius of rotation R, we shall have to consider the following angles or angular increment: $\Delta\alpha$ the angular rotation of the paired mirrors, $\Delta\theta$ the corresponding angular displacement of the fringes, ΔN the linear displacement of the micrometer mirror (in a direction normal to its face), and $\Delta\varphi$ the angle subtended by two consecutive fringes. If n is the order of the fringe we may write

$$\Delta\varphi = \Delta\theta/\Delta n \tag{1}$$

Moreover if i is the angle of incidence (45°) of the impinging beams at the mirrors and λ the wave length in question,

$$2 \cos i\, \Delta N/\Delta n = \lambda, \tag{2}$$

or on substitution,

$$\Delta\theta/\Delta N = \Delta\varphi/(\Delta N/\Delta n) = 2 \cos i\text{-}\Delta\varphi/\lambda \tag{3}$$

Again if s is the angle at the apex of the distance triangle on the base b,

$$\Delta s = 2\Delta\alpha \tag{4}$$

and

$$\Delta\alpha = \Delta N \cos i/R \tag{5}$$

and since the distance $d = b/2\Delta s = b/2\Delta\alpha$, from (5)

$$d = bR/2\Delta N \cos i = F/\Delta N \tag{6}$$

so that the sensitiveness is from (6),

$$\delta d = (2d^2 \cos i/bR)\, \delta\,(\Delta N) = \delta\,(\Delta N)/Fd^2 \tag{7}$$

If μ is the index of refraction, e the effective thickness of the plates, i.e., the difference of effective thickness of the two half silvered plates through which the beams pass, we may write as in the colors of thin plates (since the respective beams pass each plate but once)

$$n\lambda = e\mu \cos r - 2N \cos i \tag{8}$$

if r is the angle of refraction corresponding to the incidence, i. If n, i, r, alone vary while e, μ, λ, N, are fixed and since $\sin i = \mu \sin r$, i.e., if the eye travels through the field of the telescope from left to right,

$$\Delta\varphi = di/dn = \lambda/(2N \sin i - e \tan r \cos i) \tag{9}$$

so that $\Delta\varphi$ depends inversely on e and N.

When the spectrum ellipses are centered, $N = N_0$, a condition necessary for the occurrence of achromatic fringes, where,

$$2N_0 = e\ (\mu \cos r + 2B/\lambda^2 \cos r)/\cos i \tag{10}$$

if $\lambda d\mu/d\lambda = 2B/\lambda^2$ is adequate. Equation (10) may now be inserted in equation (9) and the coefficient of e, viz., the long parenthesis containing circular functions evaluated for $i = 45°$, $\lambda = 6 \times 10^{-5}$, $\mu = 1.55$, $2B/\lambda^2 = .026$. Its value is slightly greater than 1. Hence we may write approximately but with much greater convenience

$$\Delta\varphi = \lambda/e \tag{11}$$

and we thus obtain the breadth of the fringes for different values of the parameter e, roughly. It would, of course, be easy to compute the accurate value of i. This equation placed in the above equations (3), (5), (6) gives in succession,

$$\Delta\theta = \frac{2\Delta\varphi\ \Delta N \cos i}{\lambda} = 2\frac{\cos i}{e}\Delta N \tag{12}$$

$$\Delta\theta = \frac{2R}{\lambda}\Delta\varphi\Delta\alpha = \frac{2R}{e}\Delta\alpha \tag{13}$$

$$d = \frac{bR}{2\Delta N \cos i} = \frac{bR}{e\Delta\theta} \tag{14}$$

so that the measurement of the long distance d depends ultimately on the area, $2bR$, of the ray parallelogram, the differential thickness of paired glass plates, e, and the displacement $\Delta\theta$ of the achromatic fringes.

From equation (14) we obtain the sensitiveness by differentiation, or

$$\delta d = \frac{d^2e}{bR}\delta\,(\Delta\theta) \tag{15}$$

Let the angle $\Delta\theta$ or its variation be measured in a telescope of length L, and provided with an ocular micrometer, so that the angle $\Delta\theta = x/L$, x being the linear magnitude measured on this micrometer. Hence,

$$\delta d = \frac{d^2e}{bRL}\delta x \tag{16}$$

and if we introduce moderate estimates, d = kilometer = 10^5 cm., $e = 10^{-2}$ cm., $b = 200$ cm., $R = 10$ cm., $L = 50$ cm., $\delta x = 10^{-2}$ cm., then $\delta d = 10$ cm., or d should be measurable to 10 cm. at a kilometer, so far as the interferometer only is concerned. It may be noticed that in equations (11) to (14), e is variable and equal to $\lambda/\Delta\varphi$. If the plate halfsilvers traversed by the interfering beams are not equally thick

optic plate (or in general), a full compensation is secured by rotating the mirror nearest the telescope, provided it is the thinner of the pair. In such a case the system of mirrors will not be parallel, however, when the fringes are infinite in size (circles) and the zero position of the micrometer must be independently found, as one of the constants of the apparatus.

[1] See these PROCEEDINGS, 3, June, 1917, 412, 432, 436.
[2] From a Report to the Carnegie Institution, of Washington, D. C.

INTER-PERIODIC CORRELATION IN THE EGG PRODUCTION OF THE DOMESTIC FOWL

By J. Arthur Harris, A. F. Blakeslee, and Wm. F. Kirkpatrick

STATION FOR EXPERIMENTAL EVOLUTION, COLD SPRING HARBOR, N. Y., AND CONNECTICUT AGRICULTURAL COLLEGE, STORRS, CONN.

Communicated by C. B. Davenport, July 13, 1917

In no animal organism except man has the investigation of the interrelationship of the various morphological and physiological characteristics of the individual by means of the modern methods of statistical analysis applied to large masses of quantitatively recorded observations been carried out on a more extensive scale than in the domestic fowl, to which Pearl and Surface, and others associated with them, have devoted their attention for a number of years.

Notwithstanding the many problems dealt with in this series of investigations, our knowledge of the interrelationships of characters of economic importance in this organism is still far from complete. Data from breeds different from those used by Pearl and Surface are particularly needed for purposes of comparison.

In an earlier paper[1] we discussed the correlation between the concentration of yellow pigment in the somatic tissues and egg production in the White Leghorn fowl. In the present investigation we have considered the correlations between the egg production of various periods.

The intensity of the correlation between the number of eggs laid in the several individual months and the total egg production of the year as a whole is shown by the solid dots in figure 1. A curve in excellent agreement was found for the previous year.

Economically these coefficients are of the greatest importance since they make possible the selection of groups of birds of high annual egg production from the trap nest records of individual months. Biologically they are in some degree spurious because of the fact that the cor-

relation is determined in each instance between the yield of an individual month and the yield of the entire year, which is made up of the yields of all the individual months. If the source of the partial spuriousness of these constants be removed by correlating between the records of the individual months and the total production of the remaining eleven months of the year, a better biological measure of the interdependence of egg laying activity in two periods is obtained. These are the results represented by the position of the circles on the ordinates for the individual months in figure 1. There is, as shown by the shaded area, a material reduction from twelve to eleven months by excluding the month used as the first variable in determining the correlation.

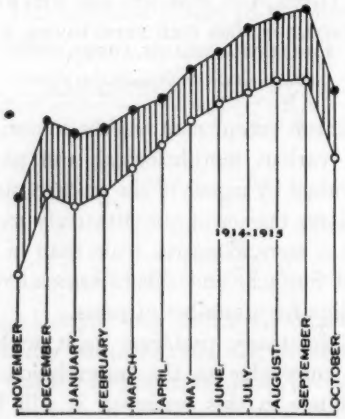

FIG. 1

The correlation between the production of single months and the production of the remaining eleven months of the year has, however, in every instance a substantial value. The coefficients range from 0.295 to 0.567 in the several months of 1913–1914 and from 0.240 to 0.567 in 1914–1915. The average reduction from the corresponding coefficients for 12 month periods is 20.45% in each year. Thus one must conclude that the birds are permanently, at least during the period of the first egg laying year, differentiated in respect of capacity for egg production.

The magnitude of the correlation coefficients measures on the universally applicable scale of -1 to $+1$ the closeness of interdependence of the egg production of the two periods. For purposes of prediction the correlation coefficients may be thrown into the form of linear

regression equations, which have been found to give reasonably good fits to the empirical means for the annual egg records of birds laying various numbers of eggs in the individual months. The slope of the lines when plotted shows there is an increase of from 2.6 to 5 eggs in mean annual production associated with a variation of one egg in monthly record. Since in practical selection groups of birds differing by far more than a single egg may be recognized, the difference in annual production secured by selecting in any month may be of very practical importance, amounting to from 30 to 60 eggs per year.

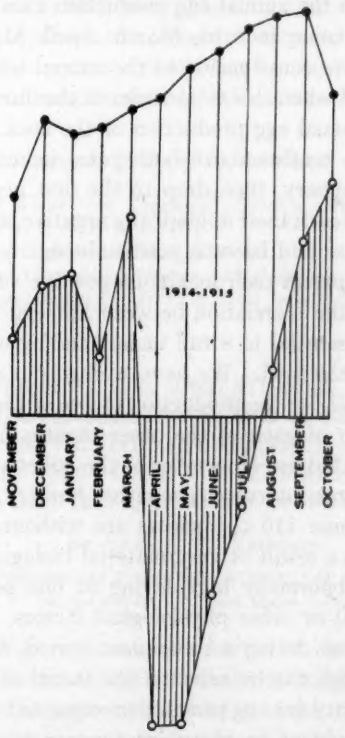

FIG. 2

While the correlation between the monthly egg record and the total annual production of the bird is the measure of the greatest practical value, forming as it does the basis for the prediction of average annual production from the observed performance of a limited period, neither it, nor the biologically more satisfactory correlation between monthly record and the production of the remaining eleven months, gives all

the information which the physiologist desires. A special coefficient due to Pearson and Harris[2] shows the correlation between the annual total and the deviation of the monthly record from the value which it should have if variation in monthly production were directly proportional to variation in the annual production. Figure 2 gives the results for 1914–1915—those for the preceding year being similar.

The coefficients show that in both years the winter months November, December, January and February and the following autumn months, September and October, show an increase over their theoretical quota of eggs when the annual egg production rises above the normal. The spring and summer months, March, April, May, June and July, show a lower relative contribution to the annual total than is theoretically to be expected when this total varies in the direction of an increase above the mean annual egg production of the flock as a whole. Thus in the diagram the coefficients in both years increase from November to December or January, then drop to the first negative value of the year in March and reach their numerically negative largest value in April, after which they rise and become positive in sign but numerically very low in August and attain their maximum positive value in October.

A knowledge of the correlation between the egg records of the individual months is essential to a full understanding of the physiology of egg production in the fowl. We have worked out sets of correlations, 110 coefficients in all, for the production of five of the individual months and the production of each of the other months of the contest year.

The months selected are November of the pullet year and the following October and three intervening months, January, April and August.

The fact that these 110 coefficients are without exception positive in sign seems to us a result of very material biological significance. It indicates that if abnormally high laying at one period tends, as the result of nutritional or other physiological factors, to result in abnormally low production during a subsequent period, the reduction is not sufficient to outweigh the influence of the initial differentiation of the birds in their capacity for egg production suggested above.

Two laws are evident in these inter-mensual correlations. These are to some degree mutually obscurant and must be considered in their mutual relations, but for the sake of simplicity may be stated categorically.

1. The correlation between the egg production of the individual months tends to become smaller as the records upon which the correlations are based become more widely separated in time.

2. There is a more intimate correlation between the egg production

of the autumn and winter months at the beginning and end of the contest year than between the egg production of these months and the productions of the intervening spring and summer months.

The relationship between the intensity of correlation and the degree of separation of the periods of egg production compared is best illustrated by the results for April and the five preceding and the six following months. The magnitude of the constants decreases with fair regularity from March to the preceding November and from May to the following October.

The second law is best exemplified by the coefficients measuring the relationship between November or October production and the record of the other months. Note that in the biological year of this investigation these months do not fall in the same but in different calendar years.

The results are to appear in detail in *Genetics*.[3]

[1] Harris, Blakeslee, Warner, and Kirkpatrick, *Genetics, Cambridge*, 2, 1917, (36–77). Also these PROCEEDINGS, 3, 1917, (237–241).

[2] Harris, *Biometrika, Cambridge*, 6, 1909, (438–443).

[3] A treatment of the relationships between part of the year's yield and the output for the entire year is in preparation by Mr. L. E. Card for a Bulletin of the Storrs Experiment Station.

TWO LAWS GOVERNING THE IONIZATION OF STRONG ELECTROLYTES IN DILUTE SOLUTIONS AND A NEW RULE FOR DETERMINING EQUIVALENT CONDUCTANCE AT INFINITE DILUTION DERIVED FROM CONDUCTIVITY MEASUREMENTS WITH EXTREMELY DILUTED SOLUTIONS OF POTASSIUM CHLORITE

By Edward W. Washburn

DEPARTMENT OF CHEMISTRY, UNIVERSITY OF ILLINOIS

Communicated by A. A. Noyes, August 4, 1917

Any theoretical interpretation, in terms of the Ionic Theory, of the properties and behavior of any solution containing electrolytes involves as one of its essential factors a knowledge of the degrees of ionization of the electrolytes present in the solution. The most reliable method of determining the degree of ionization, α_C, of a uni-univalent electrolyte at the concentration C is by means of the relationship, $\alpha_C = \Lambda_0/\Lambda_C$, where Λ_C is its equivalent conductance (corrected if necessary for viscosity effects) at the concentration C, and Λ_0 is its equivalent conductance at zero concentration.

The value of Λ_0 is usually obtained by extrapolating to zero concentration, some empirical function which is found to represent more

or less satisfactorily the observed relation between Λ and C over at least the lower portions of the concentration range. The lowest concentration to which any observer has hitherto found it practicable to push accurate conductivity measurements is 0.0001 normal. (Measurements by Kohlrausch[1]). This limitation of the concentration range open to measurement is due to the magnitude of the 'water correction' in the very dilute solutions, and to the uncertainty involved in applying it. Conductivity water which is approximately stable in contact with the atmosphere has a specific conductance of the order of magnitude of 1.10^{-6} reciprocal ohms, due to the impurities (chiefly CO_2) which it dissolves from the air. The 'water correction' which must therefore be applied to the measured value of the conductivity of a dilute salt solution may amount at 0.0001 normal to as much as 10%, at 0.00001 normal to as much as 100%, and at 0.000001 normal to as much as 1000% of the conductivity of the salt itself. And, aside from the magnitude of the correction the proper method of applying it is rendered uncertain owing to our lack of knowledge of the exact nature and amounts of the impurities present in the conductivity water, as well as to lack of sufficient constancy in the value of the conductivity of the water during the time which is required to prepare and measure the conductivity of the salt solution.

The Λ_0 values in use at present have, consequently, been obtained by extrapolation from conductivity data which in the most favorable cases do not extend below 0.0001 normal and which in most cases stop at 0.001 normal. The values of Λ_0 selected by different observers using the same conductivity data are, therefore, almost as numerous as the different functions which have been proposed for representing the data over the range open to measurement, ranging, for example, in the case of KCl at 18° from $\Lambda_0 = 128.3$ (Kraus and Bray[2]), and $\Lambda_0 = 128.5$ (Wegscheider[3]) to $\Lambda_0 = 130.0$ (Kohlrausch; Noyes and Falk[4]). Now unless the Λ_0 value for a salt can be determined with a certainty of at least 0.01 to 0.02% we cannot hope to obtain any information concerning questions which involve a knowledge of the concentration of the un-ionized molecules of strong electrolytes in dilute solutions, such questions, for example, as the behavior of strong electrolytes with respect to the requirements of the Mass-Action Law.

About eight years ago the writer became convinced that the only possible way of securing an answer to these much discussed questions was to obtain accurate conductivity data in the range of concentrations below 0.0001 normal, and that, in spite of the great difficulties which such an investigation presented, the questions at stake were of

sufficient importance to make the attempt worth while. Accordingly, with the aid of a grant from the Bache Fund of the National Academy, the investigation was begun in 1911.

The first part of the problem consisted in developing and perfecting the Kohlrausch method for measuring the conductance of electrolytes so that an accuracy of better than 0.01% could be obtained in measuring the conductance of very pure water and of these very dilute solutions. With the valued assistance of Dr. J. E. Bell and Mr. Karr Parker this part of the problem was successfully solved, and the results have already been published.[5]

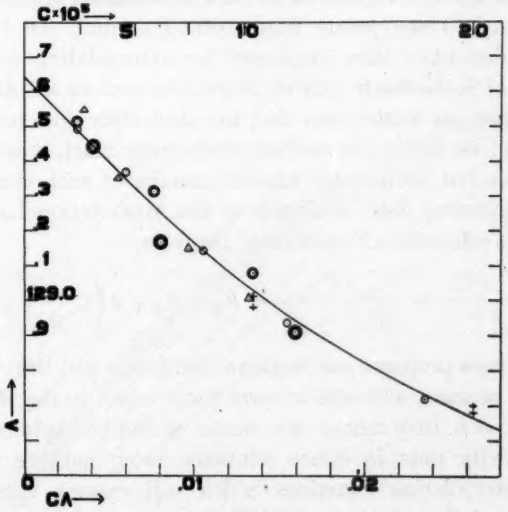

FIG. 1

The second part of the problem resolved itself into the preparation of large quantities of conductivity water which should be practically chemically pure, and the preservation of the purity of this water during the operations of preparing and measuring the conductivity of the solutions. This was successfully accomplished by means of a large quartz still connected to a three-liter quartz conductivity cell provided with platinum electrodes sealed into quartz tubes, the distillation being carried out in a current of carefully purified air. In this way three liters of conductivity water having a specific conductance at 18° of only 0.05×10^{-6} reciprocal ohms could be obtained and preserved in the conductivity cell for at least 12 hours without any appreciable increase in its specific conductance. The solutions were made up by

dropping into this cell small individual crystals of potassium chloride weighed out on an assay balance. In this way the conductivity data were carried down to 0.00002 normal.

The values obtained are shown in figure 1 (Λ, $C\Lambda$ curve), which is taken from the thesis of Dr. H. J. Weiland,[6] to whose careful work the final success of the investigation has been largely due. In this figure are represented four independent series of experiments, through which the best representative curve is drawn. The small crosses show the values found by Kohlrausch and Maltby.

In order to determine the value of Λ_0, and also the limiting value, K_0, of the mass-action expression as the concentration approached zero, it is necessary to extrapolate from 0.00002 normal. Of the various methods which have been employed for extrapolating conductivity data, those of Kohlrausch[1] and of Noyes,[4] as well as all others which are based upon the assumption that the electrolyte does not obey the Mass-Action Law within any concentration range must, it seems to the writer, be rejected because the known behavior of such electrolytes is entirely in harmony with obedience to the Mass-Action Law in sufficiently dilute solutions. Functions of the form

$$\frac{\alpha^2 C}{1-\alpha} = \frac{\Lambda^2 C}{\Lambda_0(\Lambda_0 - \Lambda)} = K_E = K_0 + k\left(C\frac{\Lambda}{\Lambda_0}\right)^h$$

which have been proposed and employed by Kraus and Bray[2] must also be rejected, because, although in form they reduce to the Mass-Action Law when $C = 0$, they cannot as a matter of fact be made to represent the conductivity data in dilute solutions, being nothing more than empirical interpolation equations which will express approximately (0.1%) the variation of conductivity with concentration between 0.001 and 2 normal. The recent function proposed by Bates,[7] $\log K_E = \log K_0' + k'\left(C\frac{\Lambda}{\Lambda_0}\right)^{h'}$ expresses very accurately the conductivity data for potassium chloride between 0.0001 normal (the lowest concentration reached by Kohlrausch) and 1 normal, but it also cannot be made to express the conductivity data below 0.0001 normal. Both the Kraus equation and the Bates equation fulfil the condition of obedience to the Mass-Action Law when $C = 0$, but they both impose upon the electrolyte an arbitrary method of approach to the condition of constancy required by the Mass-Action Law. The two methods of approach are both radically different and both wrong, since neither form of function can be fitted to the data in the most dilute solutions. In fact, any method of extrapolation which imposes an arbitrary a priori determined path by

which the values of K_E shall approach constancy must obviously be rejected if we expect to obtain reliable values for Λ_0 and K_0.

In order to avoid the errors involved in what may be called the 'arbitrary function' method of extrapolating, and also in order to avoid the uncertainties involved in attempting a direct graphical extrapolation, the following method was devised. It rests only upon the following two assumptions: (1) That as C decreases, the value of the mass-action expression K_E also decreases and gradually approaches a constant,

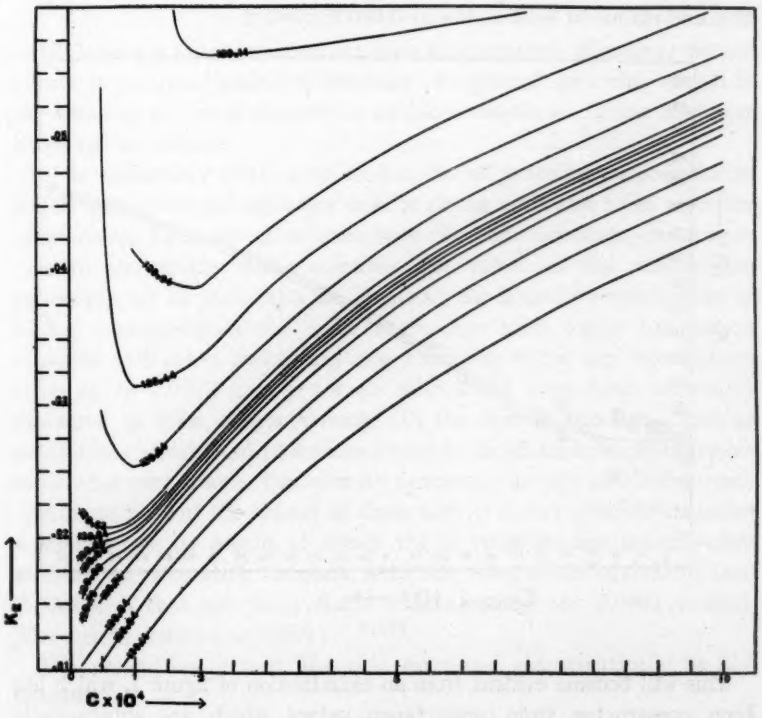

FIG. 2

K_0, at extreme dilutions; and (2) that when the value of K_E once begins to approach a constant value, it will not thereafter, that is in more dilute solutions, exhibit any erratic behavior such as a rapid rise as the concentration decreases, or a sudden fall under the same conditions. In other words, it is assumed that those influences which cause a strong electrolyte to deviate from the Mass-Action Law gradually and steadily become smaller and smaller and finally disappear at high dilutions.

The method consists simply in plotting values of K_{∞}, the mass-action expression, against values of the concentration, employing different assumed values of Λ_0 and rejecting such values of Λ_0 as cause the curve in dilute solutions to exhibit sudden changes in direction. In this way it is found that, if too small a value is employed for Λ_0, the curve will eventually shoot upward; while, if too large a value is employed, it will turn downward in the lower concentration ranges. By employing this method it is possible to determine the value of Λ_0 with a certainty of 0.01%, provided the conductance data themselves are as accurate as this and extend at least as low as 0.00002 normal.

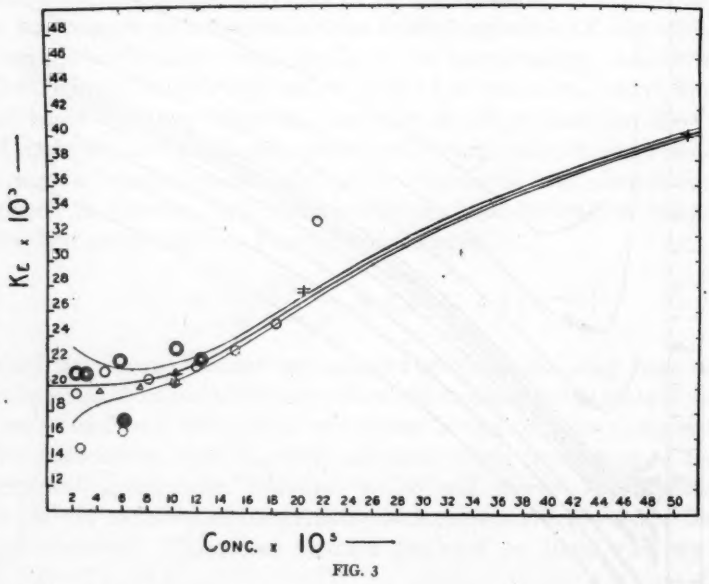

FIG. 3

This will become evident from an examination of figure 2, which has been constructed from conductance values which are substantially those represented by the curve in figure 1. It is also evident from this figure that the value of Λ_0 for potassium chloride at 18° is 129.64 ± 0.02, and that the value of K_0 is 0.020 ± 0.001.

Figure 3 illustrates the behavior of potassium chloride with respect to the requirements of the Mass-Action Law and shows that this law is obeyed within the experimental error in the concentration range 0 to 0.0006 normal. The different series of points represent independent sets of measurements. Those indicated by the dotted circles represent

a rejected series. The two bounding curves above and below the heavy curve represent the shift in the position of this 'best' curve which would be produced by a total error of 0.02%; for instance, an error of 0.01% in the concentration in combination with an error of 0.005° in the temperature of the solution. Since most of the observed points fall within the limits set by these two curves, it is evident that the agreement among them is even better than could be expected, considering all of the difficulties and chances of error involved in the work. A detailed account of Dr. Weiland's work will be published later.

With the aid of the conductivity data for potassium chloride presented above, it becomes possible to establish two general laws with respect to the behavior of strong electrolytes in dilute solutions. These laws may be stated as follows:

1. In sufficiently dilute solution (i.e., for all practical purposes below 0.0001 normal) all uni-univalent salts of strong acids and bases obey the Mass-Action Law, and all of them have the same ionization constant.

2. In sufficiently dilute solutions the values of the mass-action expression for all such salts are identical, the identity persisting up to higher concentrations the more nearly the salts under comparison resemble each other, and in any case persisting within the experimental error up to 0.0002 normal for all salts which have been accurately measured at these concentrations. In the case of two salts, such as potassium chloride and potassium bromide, for example, which resemble each other very closely, this identity persists up as high as 0.005 normal.

With the aid of the second of these laws it is now possible to derive a general rule by means of which the Λ_0 value for any uni-univalent salt can be accurately obtained from the value of the equivalent conductance of that salt at a single concentration, say 0.0001 normal. This rule is deduced as follows:

The second law stated above is expressed mathematically by the equation,

$$\frac{\Lambda^2 C}{\Lambda_0(\Lambda_0 - \Lambda)} = K_E$$

where the value for K_E is independent of the nature of the salt, and can therefore be read off from the curve in figure 3 (or preferably from a similar curve for a salt resembling as closely as possible the one under examination). Solving this expression we find (with sufficient accuracy), $\Lambda_0 = \Lambda_C\left(1 + \frac{C}{K_E}\right)$, an expression by means

of which the value of Λ_0 for any salt can be calculated from a single value of Λ_C for that salt. A convenient value of C to employ generally for this purpose is 0.0001, and for this concentration the above expression becomes $\Lambda_0 = 1.00476\ \Lambda_{0.0001}$ for all uni-univalent salts of strong acids and bases.

The reason why strong acids and bases themselves, as well as salts of weak acids and bases, are not included in the scope of the laws as formulated above, is not because there is any reason to suppose that these substances form exceptions to the laws, but merely because there are no reliable data available for testing the laws in any of these cases, nor can such data be secured except by employing extremely pure water, such as that described above.

The new rule for calculating Λ_0 has been tested at concentrations 0.0001 and 0.0002 in the case of all salts for which there are reliable data available, and in every instance the rule applied to both concentrations is found to give within the experimental error the same Λ_0 value. As an illustration of this, the data for a few of the salts whose conductivities are most accurately known are shown in the accompanying table. A general revision of Λ_0 values and ionic conductances on the basis of the above laws will be published later.

TABLE

ILLUSTRATING THE CALCULATION OF Λ_0 VALUES FOR TYPICAL UNI-UNIVALENT SALTS BY MEANS OF THE GENERAL RELATION, $\Lambda_0 = \Lambda_0\left(1 + \frac{C}{K_E}\right)$, AND DEMONSTRATING THE IDENTITY OF THE K_E VALUES OF ALL SUCH SALTS UP TO $C = 0.0002$. [MEASUREMENTS BY KOHLRAUSCH AND MALTBY,[1] CORRECTED (+ 0.02%) FOR METATHESIS BUT NOT FOR ATOMIC WEIGHTS.]

$C \times 10^4$ EQUIVALENTS PER LITER	NaCL		KNO_3		LiCl		$LiNO_3$	
	Λ_C	Λ_0	Λ_C	Λ_0	Λ_C	Λ_0	Λ_C	Λ_0
1.037	108.20	108.72	125.48	126.09	98.17	98.63	94.48	94.92
	108.11	108.63	125.54	126.15	98.11	98.57	94.44	94.88
	108.04	108.57						
$K_E = 0.0212$	Mean	108.64 ± .05	Mean	126.12 ± .03	Mean	98.60 ± .03	Mean	94.90 ± .02
2.053	107.83	108.65	125.16	126.11	97.85	98.58	94.16	94.90
	107.82	108.64	125.22	126.17	97.86	98.59	94.14	94.88
	107.82	108.64						
$K_E = 0.0268$	Mean	108.64 ± .01	Mean	126.14 ± .03	Mean	98.59 ± .01	Mean	94.89 ± .01
0.5212	108.41	108.69						
$K_E = 0.02017$								

[1] Friedrich Kohlrausch, *Gesammelte Abhandlungen*, Leipzig, 1911.

[2] Kraus, C. A., and Bray, W. C., *J. Amer. Chem. Soc., Easton, Pa.*, **35**, 1913, (1412).

[3] Wegscheider, *Zs. physik. Chem., Leipzig*, **69**, 1909, (603).

[4] Noyes, A. A., and Falk, K. G., *J. Amer. Chem. Soc., Easton, Pa.*, **34**, 1912, (461).

[5] Washburn, E. W., and Bell, J. E., *Ibid.*, **35**, 1913, (177); Washburn, *Ibid.* **38**, 1916, (2431); Washburn and Parker, K., *Ibid* **39**, 1917, (235).

[6] Weiland, H. J., *Urbana, Univ. Ill. Theses*, 1917.

[7] Bates, S. J., personal communication to the writer. See Washburn's *Introduction to the Principles of Physical Chemistry*, New York, 1915, p. 216. Bates does not propose his function as a basis for selecting the value of Λ_0. For this purpose he employs a method which, while based upon substantially the same character of assumptions as the one adopted by the writer and giving nearly the same results, does not seem so direct and simple in its application. See Bates, *J. Amer. Chem. Soc., Easton, Pa.*, **35**, 1913, (526).

ON THE GROWTH AND FECUNDITY OF ALCOHOLIZED RATS

By E. C. MacDowell and E. M. Vicari

STATION FOR EXPERIMENTAL EVOLUTION, COLD SPRING HARBOR, N. Y.

Communicated by C. B. Davenport, August 16, 1917

In the course of an experiment conducted primarily for a different purpose, we have obtained data upon the effect of large doses of inhaled alcohol on the growth and fecundity of a series of albino rats. From the time of weaning (28 days) the alcohol was administered daily. Except for the first few weeks when the doses were lighter, the rats were left in the inhalation tanks till they could no longer stand upon their feet and could move but very feebly, if at all. The purpose was to give as heavy a dose as possible without killing the animal. This took different times for different rats, and the time required on different days varied according to the intensity of the alcohol vapor in the tanks. No data were recorded as to the time required to regain normal activity, but it may be said in general that this was roughly a matter of three to four hours.

For each rat alcoholized, a normal control from the same litter and of the same sex was raised. These controls were kept in companion cages adjacent to their corresponding alcoholic sibs. Except for the alcohol treatment, all the rats were given the same care and attention.

Weekly weighings were made of all the rats and individual growth curves were plotted. From these curves the weights at the ages given in the standard growth curves of Donaldson were estimated. In making these estimations, allowances were made for temporary losses in weight due to food conditions or minor illnesses; in doing this the whole curve of the individual was considered as well as the curves of its sibs and the standard Wistar curves. The weights so obtained were averaged for the two groups of rats, and these averages plotted in figure 1.

The weights given for the first point (30 days) are mainly approximations, as the first weighings of many of the rats were not taken till after this time. For this reason the weights at 40 days have been given. It will be noted that the averages of both sets of rats for 90 days are a little low. This lowering is unquestionably the result of a reduced diet that was given to all the rats in connection with a series of behavior experiments.

The divergence shown between the two curves is sufficiently clear to make it impossible to question the conclusion that the alcoholics

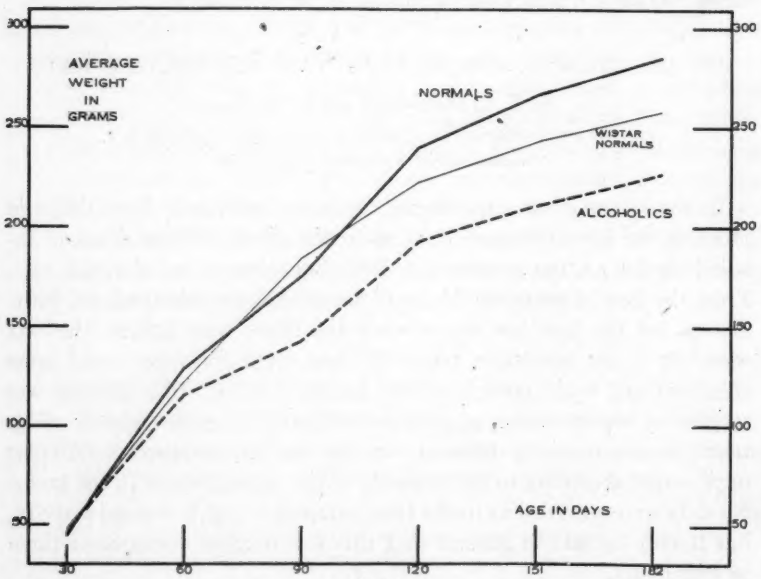

FIG. 1

have suffered a loss in weight as a result of the treatment with alcohol. The amount of this loss as shown in the curves is very close to 20% of the normal weight at 182 days. The light line in the figure was plotted from the averages given by H. H. Donaldson, *The Rat*, (Philadelphia, 1915), page 113, table 67. As all the rats here described were bred from the Wistar standard stock, the higher averages of these normals appear to indicate that the food and environmental conditions have been especially favorable. It follows from this that the lowering of the weights of the alcoholic rats is not partly due to unfavorable conditions.

In this report the males alone have been considered. As the corresponding females were used for breeding, the frequent pregnancies rendered it extremely difficult to estimate the normal weights at the specified ages. Moreover, the females are less satisfactory for this study since during the times they were nursing their young the alcohol treatment was suspended, although during pregnancy up to the time for the young to be born, they did receive the alcohol.

The reduction in the number of young born to alcoholic parents is even more striking than the loss in weight. The figures in table 2 show that, while 29 pairs of normal rats produced 300 young, 30 pairs of alcoholic rats produced in the same time 108 young. The summaries for the four lines all show a similar decrease in fecundity of the alcoholics as compared with the normals as is shown in the grand total.

The discussion and a more critical analysis of these results will be reserved for an extended account at a later date.

TABLE 1

AVERAGE WEIGHTS (IN GRAMS) OF ALCOHOLIZED MALE RATS COMPARED WITH THEIR NORMAL BROTHERS

AGE IN DAYS	ALCOHOLICS		NORMALS		DIFFERENCES IN BODY WEIGHT
	Number of individuals	Average body weight	Number of individuals	Average body weight	
		grams		*grams*	
30	27	46.2	22	45.4	0.8
40	27	70.5	22	74.5	4.0
60	27	116.1	22	128.7	12.6
90	26	142.3	22	174.9	32.6
120	22	192.5	21	239.8	47.3
151	16	211.7	18	267.0	55.3
182	10	227.1	13	285.0	57.9

TABLE 2

FECUNDITY RECORDS OF ALCOHOLIC RATS COMPARED WITH NORMAL RATS; MATINGS OF ALCOHOLICS AND THE CORRESPONDING NORMALS MADE ON THE SAME DAY, AND THE RECORD OF BIRTHS TAKEN DURING EQUAL PERIODS

GROUP	NUMBER OF PAIRS		NUMBER OF YOUNG BORN	
	Alcoholics	Normals	Alcoholics	Normals
A	10	10	23	75
B	4	3	13	31
C	7	8	30	81
KC	9	8	42	113
Total	30	29	108	300

NATIONAL RESEARCH COUNCIL

MINUTES OF THE MEETING OF THE NATIONAL RESEARCH COUNCIL HELD ON THURSDAY, APRIL 19, 1917, IN ROOMS 42 AND 43 OF THE UNITED STATES NATIONAL MUSEUM, WASHINGTON, D. C.

The Chairman of the Council, Dr. George E. Hale, presided and called the meeting to order at 10.15 a.m. The following members were present: Dr. Alsberg, Dr. Baekeland, Dr. Bogert, Dr. Carty, Dr. Clarke, Dr. Conklin, Dr. Coulter, Dr. Davis, Dr. Day, Mr. Dunn, Admiral Earle, Mr. Freeman, General Gorgas, Dr. Hale, Dr. Holmes, Dr. Keen, Mr. Manning, Dr. Millikan, Dr. Moore, Dr. Noyes, Dr. Pupin, Mr. Skinner, General Squier, Dr. Stratton, Mr. Swasey, Chief Constructor Taylor, Dr. A. E. Taylor, Dr. Vaughan, Dr. Walcott, Prof. Webster, Dr. Welch, Dr. Whitney, Professor Wood, Dr. Yerkes; and the Secretary, Cary T. Hutchinson.

The minutes of the organization meeting of the Council held in September, 1916, and of meetings of the Executive Committee held since then, were presented by the Secretary, and upon motion were adopted as printed in the PROCEEDING OF THE NATIONAL ACADEMY OF SCIENCES.

The Chairman stated that the main purpose of the present meeting was to offer an opportunity for a discussion and determination of methods for advancing the work of the Council as affected by actual war conditions. He spoke particularly in this connection of the work of the Foreign Service Committee of the Council.

The Chairman referred to the material assistance furnished to the Council by the Engineering Foundation, and to the need for additional donations with which to continue its work.

Dr. Stratton as Secretary of the Military Committee, presented a report for that Committee laying emphasis upon the customary mode of procedure in selecting and detailing a scientist, or a group of scientists, to work upon definitely specified problems in direct co-operation with representatives of the War Department and the Navy Department of the Government.

Discussion took place with reference to the desirability of publication of lists of problems for distribution among men of science.

The Chairman mentioned the appointment of Dr. Millikan as Vice-Chairman and Executive Officer of the Council, and the presence in Washington of the chairmen of many important committees.

Modes of procedure to be adopted in organizing the Washington Office of the Council, and in bringing about the necessary co-operation between committees were discussed, and the need was emphasized for the publication of statements concerning the activities of the Council, particularly for the use of members of the Council and of Chairmen of Committees.

Discussion also took place concerning the availability of men for special work, and concerning methods to be used in designating them for such work.

The Chairman, in the absence of Professor Chittenden, submitted a report of progress for the Committee on Research in Educational Institutions.

Dr. Millikan spoke of the work of his office and of his efforts to bring about co-ordination in the solution of specific problems.

Dr. Coulter spoke of the activities of the Botany Committee, this leading to a discussion of co-operative measures necessary in dealing with the subject of botanical raw materials.

Dr. Carty outlined plans for the work of the Committee on Industrial Research.

Dr. Noyes submitted statements concerning the existing conditions of the nitrate problem with particular reference to its association with agricultural work. He reported that the Committee of the Council on this subject as recommended in its report to the Secretary of War has been superseded by an official Government committee.

In the absence of Dr. Stratton, the Chairman reported progress for the Committee on Census of Research.

Dr. Bogert, Chairman of the Chemistry Committee, discussed general questions of organization and spoke of the close co-operation obtained in the work of his Committee between laboratories of individuals, universities, manufacturers, and the Government.

The Chairman, in the absence of Professor Pickering, reported upon the work of the Astronomy Committee.

Dr. Vaughan submitted a detailed report for the Committee on Medicine and Hygiene, calling attention to suggestions regarding problems, and to the advisability of appointment of special committees to consider these problems.

In the absence of Dr. Cannon, the Chairman reported progress for the Physiology Committee.

Dr. Davis, Chairman of the Geography Committee, reported upon the immediate need for increasing the preparation of topographic maps, for the publication of aero maps, and for the preparation of military hand books for various parts of the United States and for Central Europe. He also expressed the hope that the next census of the United States would provide for a physiographic division of the country.

Dr. Clarke, Chairman of the Geology Committee, outlined problems relating to military affairs and suggested means of co-operation on this subject.

Dr. Holmes, Chairman of the Anthropology Committee, read a report and stated that the activities of his Committee at present relate to questions concerning recruits and methods of examination, and also to statistics arising therefrom.

Mr. Dunn, Chairman of the Enginering Committee, spoke of the formation of this Committee, and of its co-operation with the national engineering societies.

Dr. Moore, Chairman of the Mathematics Committee, reported that the Committee is in a position to consider and aid in the solution of any problems of a mathematical nature which may be submitted by the Government.

Dr. Yerkes, Chairman of the Psychology Committee, emphasized the need of psychological studies of recruits, and mentioned the far-reaching significance of such studies in the selection of men for special purposes.

The meeting adjourned at 1.50 p.m.

CARY T. HUTCHINSON,
Secretary.

NATIONAL RESEARCH COUNCIL

MEETINGS OF THE EXECUTIVE COMMITTEE

The twenty-fourth meeting of the Executive Committee convened in the offices of the Council in the Munsey Building, Washington, D. C., on July 12, 1917, and was called to order at 9.30 a.m. by the Chairman of the Counci .

Messrs. Bogert, Hale, Millikan, Pupin, and Stratton were present and, by invitation, Messrs. Durand and Mendenhall.

The Chairman reported:

1. That the Director of the Council of National Defense has requested the National Research Council to submit to him regular monthly reports of its activities, and that in order to comply therewith the Chairmen of the Committees of the Research Council have been asked to forward reports periodically to the Washington office with regard to the nature, organization and progress of investigations, and the results of researches, inquiries, and conferences bearing upon the work of the Council.

2. That Admiral William S. Benson and Dr. W. F. Durand have been appointed members of the Council by the President of the National Academy of Sciences.

The Chairman read a letter from General Squier, dated July 2, requesting the Research Council to act as the advisory agent of the U. S. Signal Corps in the organization of its various scientific activities and in the solution of research problems and suggesting that Dr. Millikan apply for a Major's Commission in the Officers' Reserve Corps, for detail in charge of this work. Upon motion it was voted that this request be complied with.

Before this formal arrangement was entered into with General Squier, upon his request that the Council recommend some one to take charge of the sound ranging work of the Army, Dr. Augustus Trowbridge of Princeton was designated. Upon motion the Executive Committee ratified this action.

Dr. Millikan reported that General Squier had referred to the Council a cablegram from Colonel Russell of the American Expeditionary Force in France, asking that a research and inspection group be sent over to France at once. He also stated that Major Carty has designated Mr. E. H. Colpitts and Mr. H. E. Shreve for signal work in this connection.

Dr. Durand reported on the question of the development and production of aeronautic instruments, and upon the need for a scientific advisor in this field. It was voted, upon motion, that the National Research Council recom-

mend to General Squier the appointment of Dr. C. E. Mendenhall in charge of the design and development of all instruments used on airplanes.

Dr. Millikan reported that on recommendation of the National Research Council the General Munitions Board held a special meeting devoted to the problem of gas warfare, to which representatives of the Departments of the Government having any connection with the ubject were invited, as well as members of the Noxious Gases Committee of he Council. Dr. Ames and Dr. Dakin of the Foreign Service Committee were also present; and the subject under discussion was presented at leng h by M. Grignard of the French Scientific Mission. As a result of this meeting the Chairman of the General Munitions Board was authorized to appoint a special committee to make recommendations concerning a pro er or anization of gas warfare. Dr. Millikan has been appointed on this committee as a representative of the National Research Council.

Upon recommendation of Dr. Bogert, as Chairman of the Chemistry Committee:

The appointment of a Subcommittee on Synthetic Drugs with Professor Julius Stieglitz of the University of Chicago as Chairman, was approved.

The appointment of Dr. Prevost Hubbard as Chairman of the Subcommittee on the Chemistry of Cements and Related Building Materials, upon the resignation of Dr. A. S. Cushman, who has entered the service of the War Department, was approved.

The appointment of Dr. George H. A. Clowes and Professor J. U. Lloyd as members of the Subcommittee on the Chemistry of Glue and other Colloids was approved; also the appointment of Mr. David Wesson as Vice-Chairman of the Subcommittee on Fats, Fatty Oils, and Soaps.

The Submarine Committee of the National Research Council with the following membership was approved: R. A. Millikan, Chairman; H. D. Arnold, W. F. Durand, Irving Langmuir, Frank B. Jewett, C. E. Mendenhall, Ernest Merritt.

It was decided that the necessary travelling expenses of the group working at New London be borne by the Research Council, this being A. A. Michelson, Chairman; Ernest Merritt, Vice-Chairman; H. A. Bumstead, Max Mason, E. F. Nichols, G. W. Pierce, H. A. Wilson, and John Zeleny.

The following appropriations were made: $300 to be expended under the authorization of the Vice-Chairman of the New London Committee for expenses in connection with submarine investigation; $670.62 for purchase of a portable house for use at the station; and $30 to Dr. H. A. Wilson for the purpose of making a condensing lens for sound rays.

The appointment of a Botanical Raw Products Committee with the following membership was approved: Edward M. East, Chairman; Oakes Ames, L. H. Dewey, Henry Kramer, George T. Moore, John E. Teeple, and additional members to be appointed later.

The organization of a Subcommittee on Forest Products of the Botany Committee was approved. The Chairman of the Council was authorized

in consultation with the Chairman of the Botany Committee to select the Chairman and members of this subcommittee.

The appointment of the Committee on Anthropolgy with the following membership was approved: W. H. Holmes, Chairman; Ales Hrdlicka, Secretary; Charles B. Davenport, Madison Grant, Frederick L. Hoffman, E. A. Hooton, George M. Kober, Tom A. Williams. A report of this committee was presented, a copy of which had been sent to the Secretary of War, its recommendations having also been presented to the General Medical Board of the Council of National Defense.

The meeting adjourned at 12.10.

The twenty-fifth meeting of the Executive Committee convened in Room 518 Munsey Building, Washington, D. C., on July 23, 1917, and was called to order at 9.35 a.m. by the Chairman of the Council.

Messrs. Bogert, Conklin, Dunn, Hale, Millikan, Pearl, Pupin, and Stratton were present and, by invitation, Messrs. Durand and Mendenhall.

The Chairman read a letter from Brigadier-General Crozier reporting that Col. E. B. Babbitt, a member of the Committee on Noxious Gases of the Council, had been appointed to other duty in the War Department, and that Capt. Earl J. W. Ragsdale had taken Colonel Babbitt's place in the Bureau of Ordnance. Upon his recommendation therefore, Captain Ragsdale was substituted as a member of the Committe on Noxious Gases in place of Colonel Babbitt.

Upon recommendation of Dr. Hale, the sum of $100 was appropriated for current and miscellaneous expenses of the Astronomy Committee.

The Chairman stated that, after conference with the Chairman of the Botany Committee, he wished to recommend the appointment of Dr. Irving W. Bailey of the Bussey Institution as Chairman of a Subcommittee on Forestry of the Botany Committee. Upon motion, this appointment was accordingly made.

The Chairman stated that need had arisen for funds to carry on work of experimentation in connection with the investigation of devices for the magnetic detection of submarines now in progress by Dr. L. A. Bauer, Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. He also stated that this work had the approval of the President of the Carnegie Institution of Washington. Upon motion, an appropriation of $500, or as much thereof as may be needed, was made from the funds of the Council for the assistance desired in this connection.

Dr. Hale reported that he had recently visited the work of the special committees of the council at Nahant, Massachusetts, and New London, Connecticut, outlining the nature of investigations carried on in each place. Upon motion, it was voted that an appropriation of $2,000, or as much thereof as may be needed, be made to defray the miscellaneous expenses incident to the work of the Committee at New London.

At 9.50 the Chairman announced that the meeting would resolve itself into a joint meeting of the Executive Committee and of the Military Committee of the Council, to hear reports and recommendations of the members of the Foreign Service Committee who had returned from Europe. (A report of this conference will appear later.)

The twenty-sixth meeting of the Executive Committee convened in the offices of the Council in the Munsey Building, Washington, D. C., on July 31, 1917, and was called to order at 10.10 a.m. by the Chairman of the Council.

Messrs. Hale, Noyes, Pearl, Stratton, Vaughan, and, by invitation, Dr. Durand, were present.

The Chairman reported the recent death of Dr. William Bullock Clark, Chairman of the Subcommittee on Roads and Road Metals of the Geology Committee of the Council.

The question of defraying the cost of publication of articles relative to the work of the National Research Council in the Proceedings of the National Academy of Sciences was discussed and, upon motion of Dr. Noyes, it was voted to appropriate from time to time such sums as may be necessary to pay the cost on a pro rata basis of space used, of publishing all such reports and articles.

Upon recommendation of the Chairman of the Chemistry Committee, the following appointments were made to membership in Subcommittees of this Committee.

Sub-Committee on Biochemistry: Prof. FRANK P. UNDERHILL, Yale University, New Haven Conn.; Chairman, to replace Dr. A. E. Taylor, resigned.

Sub-Committee on the Chemistry of Ceramics: Mr. A. V. BLEININGER, U. S. Bureau of Standards, Pittsburgh, Pa.; Mr. L. E. BARRINGER, General Electric Co., Schenectady, N. Y.

Sub-Committee on the Chemistry of Leather: Mr. FRITZ H. SMALL, 38 Berwick Street, Worcester, Mass.; Mr. JOHN H. YOCUM, 325 Academy Street, Newark, N. J.; Mr. H. C. REED, 227 Fulton Street, New York City.

Sub-Committee on the Chemistry of Forest Products: Dr. C. P. WINSLOW, Forest Products Laboratory, Madison, Wis.

Sub-Committee on the Chemistry of Dyestuffs: Mr. WM. M. GROSVENOR, 50 East 41st Street, New York City; Mr. L. DACOSTA WARD, 320 So. Broad Street, Philadelphia, Pa.; Mr. R. C. HUSTON, Michigan Agricultural College, East Lansing, Mich.

Sub-Committee on the Chemistry of Fermentation: Dr. H. S. PAINE, U. S. Dept. of Agriculture, Washington, D. C.; Dr. MAX HENIUS, 1135 Fullerton Avenue, Chicago, Ill.

Sub-Committee on Synthetic Drugs: Dr. W. A. PUCKNER, 535 North Dearborn Street, Chicago, Ill.; Prof. MOSES GOMBERG, University of Michigan, Ann Arbor, Mich.; Prof. ROGER ADAMS, University of Illinois, Urbana, Ill.

Dr. Hale reported that he soon expects to return to California, and discussion took place thereupon relative to the conduct of affairs of the Council during his absence. It was voted that meetings of the Executive Committee of the Council he held hereafter about once a month, or at such times as business demands, and that notices of such meetings be sent in advance accompanied by tentative orders of business.

The Chairman presented a letter from the U. S. Commissioner of Patents requesting the co-operation, advice and assistance of the National Research Council in questions of organization and conduct of affairs at the Patent Office. Preliminary correspondence with the Commissioner of Patents on this subject was also read. After discussion, a special committee consisting of Prof. W. F. Durand, Chairman, Dr. R. A. Millikan and Dr. S. W. Stratton, was appointed to confer with representatives of the Patent Office and report at a subsequent meeting of the Executive Committee relative to appropriate action which the Council may take in this matter.

The meeting adjourned at noon.

Subject to ratification at the next meeting of the Executive Committee, the Chairman subsequently appointed a special committee consisting of Dr, Millikan, Chairman, and Messrs. Bogert, Durand, Mendenhall, Stratton. and Vaughan, to meet once a week to consider questions relating to the conduct of affairs of the Council in intervals between the meetings of the Executive Committee.

CARY T. HUTCHINSON, *Secretary.*